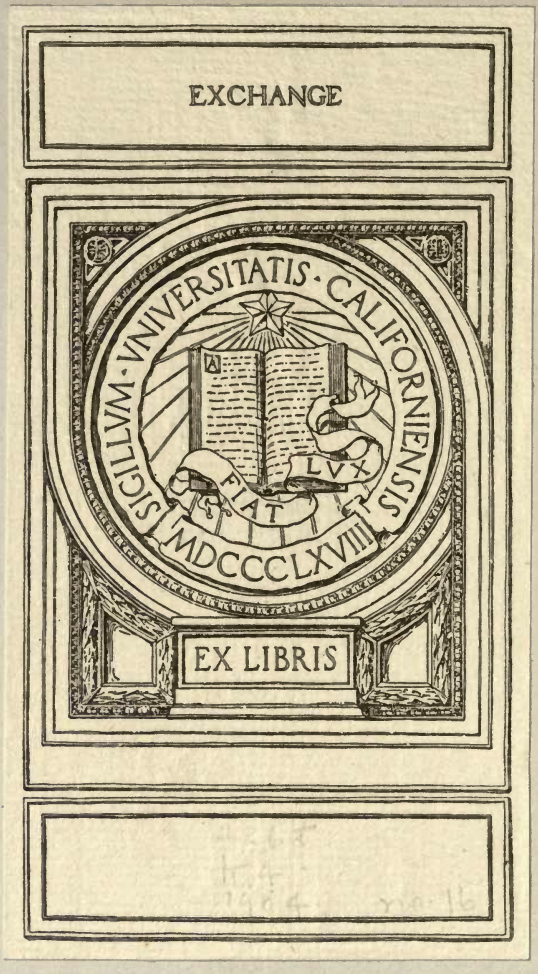
Kentucky Geological Survey.

Bulletin No. 16
Serial No. 19

The Waverlain Formations of East Central Kentucky
AND
THEIR ECONOMIC VALUES.

1912



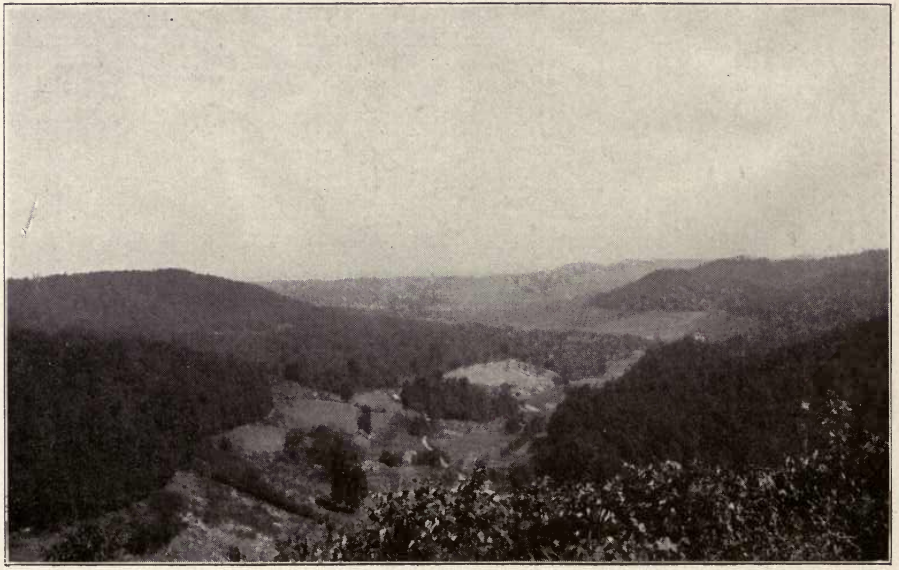


Fig. 1. Peneplain Near Esculapia Springs.

Kentucky Geological Survey

CHARLES J. NORWOOD, Director.

BULLETIN No. 16
SERIAL No. 19

Preliminary Report

ON

The Waverlian Formations

OF

East Central Kentucky

AND

THEIR ECONOMIC VALUES.

By
WILLIAM CLIFFORD MORSE
and
AUGUST F. FOERSTE.

Printed by the Interstate Publishing Co.
1912.

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PREFATORY.

His Excellency, JAMES B. MCCREARY,

Governor of Kentucky.

Sir: This is one of the several reports the printing of which has been delayed, as noted in my Biennial Report of Progress for 1910 and 1911. The report is divided into two parts. Part I. is devoted to stratigraphy, and Part II. to a review of the economic values of the several stratigraphic divisions.

The value of the report will be appreciated by all who have to deal with problems in stratigraphy presented by the Waverly Formations in Kentucky, problems that must be solved before the economic values of regions underlaid by Waverly beds can be determined intelligently. It is of especial importance in the study of oil and gas horizons, because of changes that are shown to occur in the character, thickness, and areal extent of certain divisions of the series in their southward extension from the Ohio river; and it is also of importance, for the same reason, in the work of mapping areas of beds especially fit for high grade building stones and for abrasives, and of shales and clays suitable for ceramic purposes and for cements. It is now known, as a result of the work represented by this report, that much of what has hitherto been regarded as Berea underlying extensive areas is in some instances Buena Vista (noted for yielding fine building stones), and in others Bedford (chiefly shales and clays); that the Berea sandstone (an important source of oil in Ohio and West Virginia) so changes in character and thickness southwestardly from the Ohio—finally thinning to only a few inches—that former views as to its importance with respect to extensions of oil and gas territory in Kentucky need revision;

that the representative of the noted "Euclid" building stone of Cleveland occurs in the northern part of the area covered by the report; and that the phosphatic nodules hitherto supposed, by many, to belong at the base of the Waverly, just above the Devonian (Ohio) black shale, really belong higher up, in the lower part of the Cuyahoga member of the Waverly, and, under normal conditions, should be searched for there.

It is known that the Waverly section as found west of the Ordovician area and in the south-central part of the State is notably different from that presented in the region discussed in this report; that beds present in this region become more calcareous and that limestones not present here come in. It was intended, therefore, that the study of the formations should be carried around the rim of the Ordovician area to the Ohio river in Bullitt and Jefferson counties, and continued, also, so as to cover the long and broad strip extending southwestardly to the Tennessee line. In the aggregate considerable has been done toward that end, but not sufficient to warrant preparation of a report at this time on the area as a whole. Much useful information on the character of the Waverly in its southwestardly extension will be found in the reports on Green, Taylor, Adair, and Rockcastle counties, which should soon be in type, and in the report of Mr. Munn (ready for printing)—covering work carried on in cooperation with the U. S. Geological Survey—on the oil fields of Wayne county.

Very respectfully,

C. J. Norwood,

June 1, 1912. *Director.*

LETTER OF TRANSMITTAL.

His Excellency, AUGUSTUS E. WILLSON,

Governor of Kentucky.

Sir: I have the honor to transmit for publication a report on the Waverlian formations and their economic values in Greenup, Lewis, Fleming, Carter, Rowan, Bath, Menefee, Morgan, Montgomery, Clark, Powell, and Estill counties, by W. C. Morse and August F. Foerste.

Very respectfully,

CHARLES J. NORWOOD,

Director, State Geological Survey.

January 3, 1910.

LETTER OF SUBMITTAL.

PROF. CHARLES J. NORWOOD,

Director, Kentucky Geological Survey.

Sir: I have the honor to submit herewith a report on the Waverlain formations of East-Central Kentucky by Dr. August F. Foerste and myself. The report deals more particularly with the lower formations, since a division of the upper portion of the series could not be attempted in the time at our disposal. Hence, the report is of necessity a preliminary one to a further study of the series.

To your broad policy, no small part of the credit is due for even a preliminary report in so short a period.

Respectfully,

WM. CLIFFORD MORSE,

Assistant Geologist.

July 27, 1909.

NOTE.

PROF. C. J. NORWOOD,

Director of the Geological Survey of Kentucky.

Dear Sir:

In pursuance with your directions I have carefully read the manuscript presented by Mr. W. C. Morse. The subject was thrashed out rather thoroughly in the field, and I am in perfect agreement with his views. I take advantage of this opportunity in expressing my deep appreciation of having had the privilege of working with such an acute observer as Mr. Morse on such an interesting problem. The familiarity of Mr. Morse with the corresponding strata in Ohio permitted a rapidity and accuracy of work which otherwise would have been impossible.

Respectfully,

AUGUST F. FOERSTE,

Assistant Geologist.

December 21, 1909.

PART I.

STRATIGRAPHICAL GEOLOGY.

From July 21 to September 9, 1908, a somewhat hasty study of the Lower Carbonic stratigraphy of East-Central Kentucky was made. Work was begun along the Ohio river, at Vanceburg, and continued southwestward to the Kentucky river, at Irvine.*

The early and excellent results are due in no small degree to the broad policy of Professor Charles J. Norwood, Director of the Survey. Professor Norwood desired information about the central field first, but yielded this point and permitted the work to be commenced at the known (Ohio river) area and pushed to the unknown.

From the Ohio river southwestward the changes and thinning of the lower formations of the Waverly series were traced from point to point. It is quite improbable, if not impossible, that the correct stratigraphy could have been determined by working in the reversed direction.

*A brief account of the results of this study was published in the Journal of Geology, Vol. XVII, pp. 164-177, 1909.

ORIGIN OF THE TERM WAVERLY AND ITS LIMITS.

The first use of Waverly as a geological term dates back to 1837 and 1838, during the first geological survey of Ohio. After describing the "Argillaceous slaty rock, or shale stratum," (Ohio shale), Briggs states that "Superimposed upon the stratum above described occurs a series of alternations of sandstone and shale. . . . . As some of the most beautiful stones that have been obtained were quarried at Waverly, we may, for the present, denominate these rocks the Waverly sandstone series."[1]

Briggs gave the "Conglomerate," as the upper limit of the Waverly. Some objections have been raised to this. The Maxville limestone when present occurs between the Ohio shale and the Sharon conglomerate and at the top of the Waverly. Their "conglomerate" also includes in some places a stratum now known as the Black Hand formation. The selection of "Conglomerate" as an upper limit is seen, therefore, to be an unhappy choice. If however, the only place where the upper contact was mentioned be visited, at Jackson, the Maxville will be found wanting, the conglomerate will be the Sharon, and the section will contain the full Waverly as known today. Morse has also shown that a limestone, which is probably the Maxville, was placed, at least tentatively, in the Pennsylvanian, by these men.[2]

The term "fine-grained sandstone" was used in place of the Waverly by Briggs and others in the Second Annual Report. Waverly was revised by Andrews, however, in the next report, the Report of Progress in 1869. This was the first report of the second geological survey. If there is any question as to the upper limit of the Waverly series as defined by Briggs it is settled by Andrews' report. He says "a group of sandstones and shales, measuring on the Ohio river 640 feet in thickness (from the Black Slate

1. Report of C. Briggs, Jr., Fourth Assistant Geologist, Geol. Surv., Ohio. First Annl. Rept., pp. 79,81, 1838.

2. Morse, W, C., "The Maxville Limestone of Ohio," Ohio Geological Survey, Bull. 13, November, 1910. Morse, W. C., "The Fauna of the Maxville Limestone." Proceedings, Ohio Acad. Sci. vol. 5, part 7, 1911.

to the base of the Sub-carboniferous Limestone in the Kentucky hills), rests conformably upon the Black Slate. It takes its name from the town of Waverly, in Pike county, where the stone has been extensively quarried."[3]

SUBDIVISIONS OF THE SERIES.

The Waverly series has been divided into a number of formations. The names applied to these sub-divisions are manifold. To trace them in their multi-manifold uses is confusing and often leads to utterances in suppressed breath. Thanks to Prosser for his untiring labors. He has brought order out of chaos and given us a definite classification.[4] To give the history of the various terms would be superfluous after his excellent paper on" The Classification of the Waverly Series of Central Ohio." That there may be no question, however, as to the present application of these terms they are given in the following table. The table also shows the position and relation of the superjacent formations.

Carbonic system.	Pennsylvanian series.	Monongahela formation.		
		Conemaugh formation.		
		Allegheny formation.		
		Pottsville formation.		Homewood sandstone.
				Mercer limestone and coal.
				Upper Massillon sandstone.
				Wellston coal (No. 2).
				Lower Massillon sandstone.
				Sharon coal (No. 1).
				Sharon conglomerate.
	Mississippian series.	Maxville limestone.		
		Waverlian.	Logan formation.	
			Black Hand formation.	
			Cuyahoga formation.	Buena Vista. City ledge.
			Sunbury shale.	
			Berea formation.	
			Bedford shale.	

3. Andrews, E. B., Report of Progress in the Second District, Geol. Surv., Ohio, Rept. Prog. 1869, p. 65, 1870.

4. Prosser, Chas. S. "The Classification of the Waverly Series of Central Ohio," Jour. Geol. Vol. IX, pp. 205-231, 1901.

THE WAVERLIAN FORMATIONS OF OHIO.

The Waverlian series and all of its subdivisions have been named and described from Ohio localities. It seems advisable, therefore, to briefly describe these formations in Ohio. Especially does this need become apparent, when some of the formations are later seen to undergo such rapid changes in Kentucky. Since there are local variations in the central, northern, and southern parts of Ohio these regions will be taken up separately.[4½]

CENTRAL OHIO.

The Waverlian is fully developed in Central Ohio. The formations are both typical and easily separated. For this reason each formation in this part of the State will be described fully.

THE BEDFORD FORMATION.

Along Rocky Fork, east of Gahanna, in Franklin county, are a series of exposures of Bedford shale. The shale is beautifully exposed in three bluffs but neither gives its complete vertical thickness. By combining these exposures the thickness is, however, found to be approximately seventy-five feet. The stratum is practically a soft argillaceous shale with an occasional calcareous or arenaceous parting. Roughly it may be divided into three zones, a lower gray, a middle chocolate, or mottled color, and an upper blue. At the base is a fossiliferous horizon in which *Macrodon hamiltoniae* Hall is rather abundant.

4½. Should a fuller treatment be desired the reader is referred to:
Prosser, Charles S., The Sunbury shale of Ohio, Jour. Geol. Vol. X, pp. 262-313, 1902.
Prosser, Charles S., and Cumings, Edgar R., The Waverly formations of Central Ohio, Am. Geol. Vol. XXXIV, pp. 335-331, 1904.

THE BEREA FORMATION.

Superimposed upon the Bedford a complete vertical section of the Berea is also to be seen on Rocky Fork. It measures thirty-eight feet and nine inches. At the base is a layer of sandstone which varies in thickness from zero to one and a half feet. In places it is a very regular layer while in others it is badly contorted. Above this layer is a zone of argillaceous shale and one of arenaceous shale, both with thin partings and with a complete thickness of six and a half feet. The remaining part of the stratum consists of medium to massive-lenticular bedded coarse grained sandstones which grow successively more massive upwards. In the vicinity of Lithopolis the Berea frequently consists of a single massive layer which varies from about two to eight feet. The upper surface is even but the lower is very irregular. It rests unconformably upon the Bedford.

THE SUNBURY SHALE.

Overlying the Berea on Rocky Fork are a few feet of black, fissile, carbonaceous shales belonging to the Sunbury. Lithologically the Sunbury is very similar to the Ohio shale from which it can only be separated by its superposition. About four or six inches from its base is a zone which is literally filled with one or two species of fossils. These are *Lingula melie* Hall and *Orbiculoidea herzeri* Hall and Clarke.

Near Lithopolis, is a small stream in which the upper and lower contacts of the Sunbury are shown. The total thickness is twenty-eight feet. The above fossils are also found at the base of the Sunbury in this vicinity.

THE CUYAHOGA FORMATION.

Superimposed upon the Sunbury is the Cuyahoga formation. At the base of the Cuyahoga in the vicinity of Lithopolis is a zone of soft argillaceous shale about five or six feet in thickness. Overlying this zone is a layer of argillaceous sandstone varying in thickness from about three to six feet. This layer is thought by Prosser to be the probable equivalent of the "City ledge" exposed along the Ohio river near Buena Vista.[5] Above the "City ledge" is a four- or five-foot interval of arenaceous shales. The next thirty-five or forty feet consist principally of *medium even bedded sandstones with shaly partings*. From its base to the top of the last interval the lower Cuyahoga measures about fifty feet and is known as the Buena Vista member.[6] The next twenty-five feet are mostly shales and complete the exposures at this place. In the upper Cuyahoga, shales predominate.

No exposure in this part of the State shows the complete vertical section of the Cuyahoga. A well record at Newark[7] gives the drift a thickness of two hundred and thirty-six feet and the lower Cuyahoga, two hundred and seventy feet. Since the mouth of the well is slightly below the upper limit of the Cuyahoga this would give a total thickness of about five hundred feet for the formation. Prosser[8] gives one hundred and fifty and five hundred feet as its two limits of variation.

THE BLACK HAND FORMATION.

Succeeding the upper Cuyahoga is the Black Hand. The formation is beautifully exposed along the Licking River gorge from a point east of Newark to Black Hand. The lower and upper contacts are shown in Quarry Run at

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5. Prosser, C. S. The Waverly Formations of Central Ohio, Am. Geol. Vol. XXXIV, p. 338.

6. Op. Cit. pp. 337-342.

7. Orton, Edward, "The Berea grit as a source of oil and gas in Ohio," Geol. Surv., Ohio, Vol. VI, p. 371, 1888.

8. Prosser, C. S. Revised Nomenclature of the Ohio Geological Formations, Geol. Surv. Ohio, Bull. 7, p. 2.

the eastern edge of Newark. The lower sixty or seventy feet are thick bedded, coarse grained sandstone. Superjacent to this is a five- to eight-foot zone of alternate layers of conglomerate and sandstone. Herrick, who was one of the earlier workers upon the Central Ohio Waverlian, named this "Conglomerate I." Overlying "Conglomerate I." are about thirty-five feet of massive-bedded, coarse-grained sandstone. Above this, in turn, is a six- or seven-foot zone of shale. From the considerable number of pelecypod fossils belonging to the genus Allorisma which occur in this shale, Herrick called it the Allorisma shale. The shale is overlain by a layer slightly thicker than one foot which varies from a conglomerate to a coarse-grained sandstone. This is "Conglomerate II." of Herrick and forms the topmost layer of the Black Hand.

THE LOGAN FORMATION.

Overlying the Black Hand is a series of thin to medium-bedded, argillaceous sandstones, of buff color. The upper contact is not clearly shown in Quarry Run and the thickness, therefore, cannot be given for this locality. That it is variable may be inferred from the fact that Morse[9] has shown that the Pottsville rests disconformably, not only upon the Maxville limestone, but in places upon the Logan as well. At the type locality, Logan, Hocking county, the Logan is one hundred and ten feet in thickness.

NORTHERN OHIO.

In the northern part of the State the Black Hand and Logan are wanting unless it be toward the Pennsylvania line. The Sunbury is not so distinct lithologically as in the other parts of the state. The remaining formations were named from outcrops in this portion of the state.

9. Morse, W. C. The Maxville Limestone of Ohio.

BEDFORD FORMATION.

This formation was named from the town of Bedford just southeast of Cleveland where it is about ninety feet thick. In this vicinity there is often a sandstone zone somewhere near the center or at the base of the formation. The zone consists of medium bedded sandstones with shaly partings. This sandstone is extensively quarried along Euclid creek just east of Cleveland. It is known to the trade as the Euclid stone and Prosser has named it the Euclid lentil.[10]

THE BEREA FORMATION.

The Berea formation was named from a town of that name southwest of Cleveland. In this vicinity it is massive bedded with some irregular bedding planes and as usual without shaly parting. In texture it is a grit and more abrasives are manufactured from it than from any other formation in the United States. It is also used very extensively as a building stone.

THE SUNBURY SHALE.

At Berea the Sunbury is a thin-bedded, bluish to blackish shale. Here the lower part of the Cuyahoga also consists of dark shales. For this reason the Sunbury is not so readily separated from the Cuyahoga as it is in the other parts of the state.

THE CUYAHOGA FORMATION.

The Cuyahoga is nicely exposed along the Cuyahoga river and in the eastern part of Cuyahoga county, whence its named. In this region the upper part consists of thin-bedded, argillaceous sandstones alternating with shales. The lower part, with the exception of a thin zone near or at the base, is composed almost exclusively of soft, argillaceous shales. In other words, it is the Cuyahoga of central Ohio with the Buena Vista sandstones above the "City ledge" wanting. It will probably be found advisable to apply the terms used in western Pennsylvania to the various components of the Cuyahoga.

10. Prosser, C. S. Manuscript unpublished.

SOUTHERN OHIO.

The important change in southern Ohio is the non-development of the conglomerate phase of the Black Hand. As a result the base and top of the formation and the top of the Cuyahoga, and the base of the Logan have not been determined. Aside from the development of a sandstone lentil in the Bedford the lower three formations of the series are typically developed and need not be further discussed. The "City ledge" and Buena Vista member, however, received their names from this part of the State and will, therefore, be somewhat briefly described.

THE CUYAHOGA FORMATION WITH ITS BUENA VISTA MEMBER AND CITY LEDGE.

Some two (?) miles west of Portsmouth, Carey's Run enters the Ohio from the north. Quite a distance up this run is the quarry of the Reitz (Wright's) Stone Company. Here is quarried the upper part of the Buena Vista sandstone. These even-bedded sandstones with shaly partings are nicely shown in Fig. 2.

About a mile farther west and parallel with the above stream is Stony Run. Along this stream are exposed the Bedford, the Berea, the Sunbury, and the lower part of the Cuyahoga. Just beyond the top of the Sunbury is the Amlin quarry. Neglecting the dip, which probably exaggerates the interval between the Sunbury and base of the quarry, we have the following section: At the base are twenty feet of blue argillaceous shale with a two or three inch calcareous, nodular layer, five or six feet above the base. The next is probably the "City ledge" with a two and a half-foot layer at the base and a two and a third-foot layer at the top separated by a one and three-fourths-foot nodular layer, which sometimes gives way to shales. A covered interval of twenty-three feet extends to the base of the quarry. In the quarry are the medium, even-bedded, argillaceous sandstones with shaly partings, with a thickness of about eleven feet. This makes the Buena Vista about sixty-one feet in thickness. Above these the shales predominate over the sandstones.

Fig. 2. Buena Vista Sandstone. (Top.)

Farther down the Ohio river, at Buena Vista, the "City ledge" was formerly quite extensively worked. From the wharf a tramway extended inland a few miles and topped a number of quarries by means of inclined planes. Along incline No. 4, and above the Ohio shale, there are about one hundred and thirty-one feet of Bedford and Berea more or less covered. By combining the upper parts of the section at inclines No. 4 and No. 5 the Sunbury shale is found to be fifteen and a half feet thick and superimposed upon it are seven and a half feet of greenish, argillaceous shales, forming the basal part of the Cuyahoga. Above these shales, at incline No. 4, the "City ledge" (Fig. 3), consists of a bottom layer, one and three-fourths feet, and a top layer, three feet, in thickness, the two separated by a four inch shaly parting. At incline No. 5 the bottom and top layers of the City ledge are each seven inches thicker than they were at No. 4. Thirteen feet of green, argillaceous shales with shaly sandstone partings are exposed above the "City ledge" at No. 4.

Fig. 3. Two Layers of Sandstone in "City Ledge," Buena Vista.

SUMMARY.

The Bedford formation, then, is seen to consist of quite an interval of soft, argillaceous shales of various colors, ranging from blue to red and chocolate. Sometimes a sandstone lentil, (Euclid lentil, in northern Ohio), is developed at or near the base. But when developed the even-bedded sandstones either alternate with shales or have shaly partings.

The Berea formation has quite a range in thickness. The basal portion, in some instances, may contain a few shales but the upper part consists of sandstone the layers of which usually grow more massive as one ascends. The bedding planes are usually uneven and inconspicuous. Seldom do the layers contain the shaly partings so conspicuous in the Buena Vista member. The thinner layers in the lower part are frequently ripple marked. The sandstones are usually coarse-grained.

The Sunbury shale is a stratum which usually varies between fifteen and twenty-five feet. It is a black, bituminous or carbonaceous, shale which lithologically cannot be separated from the black Ohio shale. A few inches above the base is, frequently, a very fossiliferous zone in which there are countless millions of *Lingula melie* Hall and *Orbiculoidea herzeri* (Hall), Herrick.

The Cuyahoga is predominately a formation of even-bedded, argillaceous sandstones alternating with shales although it may often depart from this and become more shaly. The lower fifty or sixty feet usually contain a preponderance of sandstones and constitute the Buena Vista member. The lower part of the Buena Vista almost invariably contains a few feet of shale with a sandstone in one or two layers frequently near the center. This sandstone is the "City ledge" at Buena Vista, but whether or not the sandstone occurring at this same horizon throughout such a wide territory is the same one, or different ones, at the various exposures, cannot be determined. It surely would do no great violence to the science to designate the one occurring at this horizon the "City ledge" and would be extremely convenient. With this understanding it will

be so used. The remaining part of the Buena Vista member contains even-bedded, argillaceous sandstones with shaly partings. The remainder of the Cuyahoga is more variable and nothing can be added to the characterization given at the beginning of the paragraph.

The Black Hand loses its conglomeratic phase in passing southward. Its lower and upper lines of contact have not been and probably cannot be, determined. For this reason, no further discussion of the formation is expedient.

The Logan is a formation of fine-grained, buff sandstones and shales. Since its lower limit in the southern part of the state has not been determined, its variations are not known.

The Berea of southern Ohio and of the adjacent parts of northern Kentucky may not be strictly equivalent to theBerea of northern Ohio, but may represent an unexpected development of a sandstone lentil in the upper part of the Bedford formation.[10½]

10½. Hyde, Jesse E., "The Ripples of the Bedford and Berea formations of Central and Southern Ohio, with notes on the paleography of that epoch." Journal of Geology, Vol. XIX, 1911.

THE WAVERLIAN FORMATIONS OF EAST-CENTRAL KENTUCKY.

The Waverly formations of Ohio have been discussed at some length. This has been deemed necessary, because the lower formations undergo quite rapid changes in passing from the Ohio river southward into Kentucky. The sandstones of both the Bedford and Berea disappear, leaving only shales, soon after the river is crossed. This shaly interval, possibly representing both the Bedford and Berea, grows thinner and thinner until finally only a few inches remain, but which still can be traced for a long distance. This allows the black Sunbury shale to rest almost directly upon the black Ohio shale and has caused the two to be included under the one (Ohio or Chattanooga) term. It has also permitted the Buena Vista sandstones to be confused with the Berea. The sandstones of the Buena Vista also finally disappear and in their place occurs the Linietta clay (shales).

By consulting the geological map of Kentucky the Waverlian series will be seen to be mapped as one unit. The area of outcrop is a belt extending from the Ohio river in Lewis county around the "Cincinnati Island" to the Ohio river in Jefferson county. In Casey county, at the southern end of the Cincinnati uplift axis, a branch is given off to the southwest. This last belt is very broad and increases in width as it passes southwesterly into Tennessee.

That part of the belt under consideration, namely from Lewis county to Estill county, gradually contracts in width to the southwest as the latter county is approached. The thinning out of the formations also occurs in this direction. For these reasons the data upon which the above conclusions are based will be presented in this order. To facilitate the location of the various places under discussion each one will be grouped under its proper county.

LEWIS COUNTY.

Lewis county borders the Ohio river for a long distance. Throughout nearly the whole of this extent the Waverlian rocks occur in the hills along the valley wall. The series also forms the surface rocks of nearly the whole county. The exceptions are a narrow belt along the western border of the county, one extending up the Ohio valley, and one up the deep valley of Salt Lick.

Vanceburg.—Vanceburg is the county seat of Lewis county and is located on the Ohio river. At the eastern end of the town is a high hill known as Alum Rock. Along a path ascending the hill are exposed the Ohio shale, the Bedford and Berea formations, the Sunbury shale, and the lower part of the Cuyahoga. Andrews, Orton, and Prosser carried the work upon the Waverlian series this far south and although Prosser[11] has published the section, yet it will be given here, since it is one of the most typical in Kentucky.

SECTION OF ALUM ROCK.

	Feet.	Feet.
5. **Cuyahoga formation** ..... Interval covered except a thick layer of argillaceous sandstone at the top. The sandstone contains *Taonurus*. Small phosphatic nodules are found in the basal part of the interval.	.....	39
4. **Sunbury shale,** total thickness..... Black, fissile, carbonaceous shales, which cannot be distinguished, lithologically, from the Ohio shale.		15½
3. **Berea grit,** total thickness.....	.....	22¼
Thick layer of gray sandstone.....	2½	.....
Heavy layer of rather coarse-grained gray sandstone, the upper surface excellently ripple marked.....	3	.....
Medium to thick-bedded rather coarse-grained gray sandstones, beautifully ripple-marked.....	15	.....
Arenaceous shales.....	1	.....
Layer of fairly coarse-grained gray sandstone.....	¾	.....

11. Prosser, Chas. S. The Sunbury shale of Ohio, Jour. Geol. Vol. X. pp. 292, 293, 1902

SECTION OF ALUM ROCK. CONTINUED.

		Feet.	Feet.
2.	**Bedford formation,** total thickness	.....	95 5/6
	Blue arenaceous shales and shaly sandstones. Lower part slightly covered	35	.....
	Arenaceous shales with thin sandstone partings	7	.....
	Layer of thick-bedded gray sandstone	1 2/3	.....
	Arenaceous shales with two layers of sandstone	6 3/4	.....
	Heavy layer of gray sandstone, with lower surface contorted	2 1/3	.....
	Arenaceous shales with two layers of gray sandstone	6 1/2	.....
	Layer of thick-bedded buff sandstone	1 3/4	.....
	Medium-bedded gray sandstones with shaly partings	2 5/6	.....
	Arenaceous pink shales with sandstone partings	2 1/2	.....
	Covered Interval	5	.....
	Layer of thick-bedded, buff sandstone	2	.....
	Practically covered interval with some argillaceous shales	22 1/2	.....
1.	**Ohio shale**	.....	242
	Black fissile, carbonaceous shales. About ten feet from the top, one or two linguloid shells occur. Near the central part the shales become softer and lighter in color and resemble a similar zone in the Ohio at Columbus, (Ohio). The interval (242′) is mostly exposed and extends to the level of the Chesapeake & Ohio Railroad.		

One of the important things to be noted in this section is the development of the sandstone zone, of thirty-eight feet and four inches, in the middle of the Bedford. This recalls a similar condition near Cleveland, in northern Ohio, and along Stony run, west of Portsmouth, in southern Ohio. The sandstones occur in definite, even layers, which either alternate with shales or have shaly partings. This is in marked contrast with the Berea, the layers of which are not so definite, and are without shaly partings, (as may be seen in Fig. 4), although this is the basal portion of the Berea where the layers are thinnest.

In "The Oil and Gas Sands of Kentucky" Hoeing gives a "section of the rocks in Lewis county."[12] The Berea is shown with a total thickness of seventy-five feet. The interval between the Berea and Devonian shales is given as twenty-five feet of which the upper ten are covered and the lower fifteen are clay shales. When these measurements are compared with those of Alum Rock section it

12. Hoeing, J. B. "Oil and Gas Sands of Kentucky." Ky. Geol. Surv., Bull. 1, p. 49, 1904.

seems more than probable that a goodly portion of the Bedford sandstone lentil has been included within the Berea.

The next hill east of Alum Rock is "Slate Point." A roadway also ascends this hill and along it the rocks are more or less exposed. Because of frequent covered intervals, however, the section is not so satisfactory as the one of Alum Rock. At least parts of all the formations, which were seen at the latter place, are exposed, and a few points are worthy of mention.

At this place in the bed of the Ohio river, during low water, fifteen and a half feet of Siluric limestones are exposed, and the contact of these limestones with the Ohio shales is revealed in the small run entering the Ohio. The upper contact of the Ohio shale is also exposed and for their complete thickness the hand level gave three hundred and one and a half feet. More or less covered near the upper middle of these black shales is quite an interval of soft, argillaceous shale, which grades into the black shales above. The interval is at least suggestive of the Chagrin formation of northern Ohio.

The Siluric limestones mentioned above extend from Vanceburg, on the Ohio river, southward and southwestward into Fleming county. They are correlated with the West Union bed of Ohio, overlying the Crab Orchard shales which near the top carry *Calymene clintoni*, a characteristic Clinton fossil in New York. The Crab Orchard shales, in turn, rest upon the Brassfield limestone, formerly regarded as Clinton, but evidently of older age than the typical Clinton of New York.[12½]

12½. Foerste, A. F. "Silurian Fossils from the Kokomo, West Union, and Alger horizons of Indiana, Ohio and Kentucky." Journal, Cincinnati Soc. Nat. Hist. Vol. XXI, 1909.

Fig. 4. Lower Part of the Berea, at Alum Rock, Vanceburg, Ky.

Farther up the "point" and just above twelve feet of black Sunbury shale is a covered interval of nine feet. Then comes a layer of sandstone, one foot in thickness, followed by an interval, of thirteen feet, nine inches which is mostly covered, but shows some olive shales. The position of the sandstone and the thickness of the intervals below and above it correspond very closely with the "City ledge" and its sub- and superjacent shales at Buena Vista.

The section continues up the hill for over a hundred feet and consists of even-bedded sandstones alternating with shales. Although somewhat poorly exposed there seems to be no considerable interval of shale. The top of the Buena Vista member is not, therefore, readily apparent.

On the Petersville road, about three miles from Vanceburg, the pike crosses a long hill, from the drainage system of Salt Lick to that of Kinniconick Creek. This hill is known as the Vanceburg hill. The rocks are slightly exposed on the north side of the hill, but on the south side there is an almost continuous section from the Berea to the Cuyahoga.

SECTION OF VANCEBURG HILL.

	Feet.	Feet.
3. **Cuyahoga formation,** to top of hill	.....	182⅔
Argillaceous to arenaceous shales with thin sandstone partings	16½	.....
Nodular layer of sandstone 1½ to	1	.....
Partly covered, mostly medium-bedded to shaly sandstones and shales, shales predominating	17½	.....
Layer of buff, argillaceous sandstone	⅚	.....
Mostly covered, some shales with thin, sandstone partings	7	.....
Medium to thick-bedded, buff, argillaceous sandstone with shaly partings, *Taonurus*. Building stone	15	.....
Argillaceous to arenaceous shale	2½	.....
Two layers of argillaceous, buff sandstone	1½	.....
Blue, argillaceous shale with one or two thin, sandstone partings	5	.....
Medium-bedded sandstones with shaly partings	4½	.....
Mostly covered, partly bluish, argillaceous shale	6	.....
Thick to medium-bedded, buff, argillaceous sandstone, excellent building stone	12½	.....
Thick bedded, but less regular, argillaceous sandstone	10½	.....

SECTION OF VANCEBURG HILL. CONTINUED.

	Feet.	Feet.
Medium to thick, even-bedded, argillaceous sandstone with shaly partings, excellent building stone	30	.....
Thick layer of blue, argillaceous sandstone	3½	.....
Medium to thick, even-bedded, clay sandstone with shaly partings, *Taonurus*. Excellent building stone	18½	.....
Slightly covered, mostly arenaceous shales with sandstone partings	7¼	.....
Medium to thick-bedded, clay sandstones with shaly partings.	10¼	.....
Partly covered, mostly blue, argillaceous shale	8¼	.....
Thick layer of argillaceous sandstone	1⅚	.....
Covered	½	.....
Two layers of, buff, argillaceous sandstone	1⅙	.....
Covered	1½	.....
2. **Sunbury shale,** total thickness	.....	15
Black, fissile, carbonaceous shale	.....	.....
1. **Berea formation**	.....	19½
Much disturbed, shaly interval, at the top of which is a contorted layer of sandstone, which varies in thickness from 0 to 9″	2	.....
Thin-bedded, excellently ripple-marked sandstone with shaly sandstone between	2½	.....
Blue, argillaceous shale and shaly sandstone. Some of the layers are ripple-marked. To the base of the exposure opposite the home of Thomas Pell, Jr.	15	.....

The Berea has undergone a wonderful change since leaving Vanceburg, three miles away. The medium to thick-bedded sandstones have given way to shaly and thin-bedded sandstones. The greatest disturbance seems to have been in the top of the Berea. At both Vanceburg and this place, though, there are excellent ripple marks. The superjacent Sunbury, followed by the long interval of Cuyahoga, however, makes the identification conclusive.

The slight covering at the base of the Cuyahoga, of course, hinders the identification of the "City ledge." But it also seems that, if represented, it does not stand out conspicuously in a shaly interval. The top of the Euera Vista member is also not clearly differentiated, since sandstones predominate for a long distance upward. The seventy-five feet between the 18½-foot and 12½-foot intervals are excellent building stones.

Harrison Chapel.—Harrison Chapel, formerly Kinniconick Postoffice, is about six miles south of Vanceburg and approximately three miles from Vanceburg Hill. A small interval of Ohio shale is exposed in the bank of Grassy Fork, near its mouth. Along the road, which ascends the hill to the south of the church, portions of the Berea and Sunbury are exposed above the Ohio. The Berea is much more massive here than it is at Vanceburg Hill as may be seen in the following section:

SECTION OF THE HARRISON CHAPEL HILL.

	Feet.	Feet.
4. **Sunbury shale**..... Black, fissile, carbonaceous shale, to the top of the exposure, but not of the formation.	.....	8½
3. **Berea formation.** } 2. **Bedford formation.** }	.....	97½
Medium to thick-bedded, buff sandstone, the upper part cross bedded. Ripple-marked.....	16	.....
Three layers of fine-grained, bluish sandstone, ranging up to 10 inches in thickness, and interbedded, shaly sandstone. Ripple-marked. This and the 16 feet above unquestionably belong to the Berea.....	6½	.....
Blue, arenaceous, ripple-marked shale. Since the strata are covered below, it is a question whether to refer this to the Berea or Bedford.....	6	.....
Covered interval, extending for a long distance along the highway. Probably mostly Bedford.....	69	.....
1. **Ohio Shale**..... Black, fissile, carbonaceous shale, to the creek bottom. Top of Ohio shale not determined, but probably this interval reaches to near the top.	.....	16½

At various places for a few miles on either side of Harrison Chapel, along the Petersville road, slight exposures show that the region has been somewhat disturbed. This is mostly in the form of folds and probably occurred in pre-Sunbury times, since it seems to have affected only the top of the Ohio and the Bedford and Berea. In one place the movement was sufficient to cause a fault, but the exposure was not large enough to show the amount of displacement.

Elk Lick.—Thirteen miles south of Vanceburg, at the home of J. E. Kegley, the Petersville road crosses a small run called Elk Lick. At the road side, south of this stream, is a steep hill, upon the side of which the Ohio, Berea and Sunbury are exposed. The outcrops are not all that that could be desired, yet they are the first south of Vanceburg which give us, at least approximately, the thickness of the Bedford and Berea formations. They show that these two formations have thinned from one hundred and eighteen feet to a total thickness of not over seventy-five feet in this distance.

ELK LICK CREEK SECTION.

	Feet.	Feet.
4. **Sunbury shale.** Pieces of black, fissile, carbonaceous shale directly above the sandstone layers.		
3. **Berea formation** 2. **Bedford formation** Medium-bedded sandstones, ripple-marked on the upper surfaces. Unquestionably Berea	.....	75
	7½	.....
Covered interval which probably contains the contact of the Bedford and Berea	67½	.....
1. **Ohio shale** Black, fissile, carbonaceous shales, which extend down to the level of the highway at the spring.	.....	30

Petersville.—South of Vanceburg eighteen miles, and near the head waters of Kinniconick creek, is the valley of Petersville. In the second gully west of the village school, the rocks are exposed more or less completely from the upper part of the Ohio shale to the lower part of the Cuyahoga formation. By combining the exposures of both branches of this gully, an almost continuous section is had from the top of the Ohio to the top of the Sunbury. This is the key section to the lower Waverly problem. The Bedford and Berea cannot have a total thickness of over forty-six and a half feet, showing a thinning of over seventy feet in eighteen miles or nearly thirty feet in five miles.

The sandstones, too, have also practically disappeared leaving only the shales behind. Whether these shales belong to the Bedford alone or to the Bedford and Berea is still an open question, since both formations, as shown in the section, contain sandstones at Vanceburg. If a section of about normal Berea, underlain by shales only, were obtainable somewhere in the vicinity of Elk Lick, then these forty-six and a half feet ought, probably, to be referred to the Bedford. However, such a section has not been, and probably never will be, found. The shales, possibly, belong in part to the Bedford and in part to the Berea. If this be true, they cannot be separated into the two formations from here southward, since the interval remains one of homogeneous shales.

The shales (*i. e.*, those between the Ohio and Sunbury) will be designated as the Bedford-Berea shale, from here southward, in the remainder of this report. The terms Bedford and Berea are well known geological names and Bedford-Berea shows, at a glance, the horizon represented. Should "the powers that be" rule out this compound term, then Petersville shale would be an appropriate term.

PETERSVILLE SECTION.

	Feet	Feet
4. Cuyahoga formation	.....	55½
Medium to heavy-bedded, gray, argillaceous sandstones with shaly partings	14	.....
Covered interval	41½	.....
3. Sunbury shale	.....	12½
Black, fissile, carbonaceous shales	.....	.....
2. Bedford-Berea, total thickness	.....	46 5/12
Covered, except some arenaceous and calcareous shales, which are probably ripple-marked	14	.....
Bluish to buff arenaceous shales with an occasional parting, ripple marked	17½	.....
Blue, argillaceous to arenaceous shales with an occasional calcareous or arenaceous parting	7	.....
Thin layer of sandstone	5/12	.....
Blue, argillaceous shales with a little black, carbonaceous shale at the base	4¼	.....
Covered interval	2½	.....
Soft, argillaceous shales mixed with some black shales	¾	.....
1. Ohio shale	.....	85
Black, carbonaceous shales, slightly covered	85	.....
Covered, to the water level of Kinniconick Creek at the church	10	.....

Along the road from Petersville to Noah, where it ascends the hill about one half mile north of the former place, is a small exposure. In this the black Sunbury shale is fifteen feet thick. Beneath the Sunbury are a few feet of shales or shaly sandstone. In these shales, five feet below the Sunbury, is a thin layer, two inches in thickness, the upper surface of which is distinctly ripple marked. This is strongly suggestive of the Berea horizon.

Esculapia Springs.—Elk Lick creek rises near the western border of Lewis county and flows northeasterly to the Ohio river at Vanceburg. Near its headwaters, fourteen miles from Vanceburg, is Esculapia Springs. In the highway ascending the hill, at the springs, is quite a long exposure of rocks. Unfortunately, the section usually has a covered interval at the important points. Above the Ohio and directly beneath the Sunbury shale are exposed fourteen feet of arenaceous shales or shaly sandstone. About four feet from the top of these is a three-inch layer

of sandstone with its upper surface nicely ripple marked. The significance of these thin layers of sandstone with ripple marked surfaces has already been mentioned.

GREENUP COUNTY.

Greenup county lies just east of Lewis. The rocks dip to the east and hence the upper Waverly is exposed in this county. The outcrops are limited to narrow belts along the Ohio river and along Tygarts creek and its upper tributaries.

South Portsmouth. Just across the river from Portsmouth, Ohio, is the town of South Portsmouth. The south bank of the valley rises steeply at the base and vertically near the top. From the level of the Chesapeake and Ohio Railway the top of the hill the barometer gave four hundred and fifty feet. The lower part is grass covered talus, while the upper part is a vertical cliff. The sandstones are argillaceous and buff in color. There is very little shale, the rocks being practically all massive sandstones which, when subjected to weathering, develop the honeycomb structure.

Limeville.—A few miles above South Portsmouth, is the village of Limeville (Tongs Postoffice). From the Chesapeake and Ohio tracks to the base of the Lower Carbonic limestone is an interval of two hundred and forty-one feet, of which the lower eighty-seven are covered and the upper one hundred and fifty-four are upper Waverlian strata. They consist of argillaceous, buff sandstones and shales. No attempt was made to divide them into formations, because of their lithological homogenity.

FLEMING COUNTY.

Southwest of Lewis, is Fleming county. East and southeast of Flemingsburg, the county seat, are a few outliers of Waverlian rocks. The western edge of this series

also covers a narrow strip along the eastern side of the county.

Fox Springs.—Some eight or ten miles east of Flemingsburg, is Fox Springs. From Wallingford Postoffice to Fox Springs the road crosses a high hill. On the western side of the hill the rocks are more or less exposed for a long interval and here the following section was made.

FOX SPRINGS SECTION.

	Feet	Feet
5. **Cuyahoga formation**	.....	82
Argillaceous shale with a ferruginous, nodular layer at top, slightly covered	24	.....
Top of the Buena Vista member. Thick, even-bedded, argillaceous, buff sandstones alternating with shaly intervals. Building stone	32½	.....
Soft, blue, argillaceous shale	¾	.....
Layer of argillaceous, buff sandstone. *Taonurus*	1	.....
Soft, bluish and whitish, argillaceous shales with blocks of sandstone which are probably from above. Slightly covered	23¾	.....
4. **Sunbury shale,** total thickness	.....	16½
Black, fissile, carbonaceous shale. A foot or two at the top is slightly softer and lighter in color	.....	.....
3. **Bedford-Berea shale,** total thickness	.....	32½
Blue, argillaceous shales with arenaceous and calcareous partings. Slightly covered at the base	18½	.....
Covered interval	14	.....
2. **Ohio shale,** total thickness (?)	.....	189½
Black, fissile, carbonaceous shale. Probably none included in the covered interval above	172	.....
Soft, blue, argillaceous shales alternating with black shales.	17½	.....
1. **Crab Orchard shale** (?)		
Soft, blue, argillaceous shale at top with some arenaceous or calcareous partings	.....	.....

ROWAN COUNTY.

Rowan county lies just south of Vanceburg. In area of Waverlian outcrops in this part of the State it is next to Lewis county. Save for a strip of younger rocks along the eastern border of the county and for a narrow belt of older rocks along Licking river and Triplett creek, its surface formations belong to the Waverlian.

Farmer.—Licking river forms the southwestern boundary line of Rowan county. Farmer, just within the limit of the county, is located on the east bank of the river and on the Lexington Division of the Chesapeake & Ohio Railway. There is a small stone quarry at Farmer; one two or three miles east at a flag station known as Freestone; and another one or two miles still farther east, at another flag station called Rockville (Freestone Postoffice.)

Freestone Station.—Freestone is on the west bank of Triplett creek and here are located the quarries of the Kentucky Freestone Company. The stone is lowered from the quarries to the railway by means of an incline plane. Along this incline the following section was measured.

SECTION AT FREESTONE STATION.

	Feet	Feet
4. **Cuyahoga formation**.....	.....	26
Top of Buena Vista member. Medium to thick-bedded, argillaceous, blue sandstones with shaly partings. The exposure was not continuous, since the soil and debris were dumped against the quarry face.....	25	.....
Soft, blue, argillaceous shale.....	1	.....
3. **Sunbury shale,** total thickness.....	.....	15½
Black, fissile, carbonaceous shale.		
2. **Bedford-Berea shale,** total thickness.....	.....	25
Argillaceous and arenaceous shales with shaly sandstone partings. Some of the partings slightly nodular and ferruginous.		
1. **Ohio shale**.....	.....	32
Black, fissile, carbonaceous shale, to level of Chesapeake & Ohio Ry.		

Rockville Station.—One or two miles east of Freestone Station, is Rockville (Freestone Postoffice) Station. From the east and west highway a fork is given off to the north. This fork of the road ascends the hill just west of the Kentucky Bluestone Company's quarry. In the gutter along side the road, was exposed the following instructive section.

SECTION AT ROCKVILLE STATION.

		Feet	Feet
	Soil to the level of the peneplain	15	.....
4.	**Cuyahoga formation**	.....	90
	Soft, blue, argillaceous shales with an occassional ferruginous parting. The lower two feet covered, but probably shales	35	.....
	Soft, blue argillaceous shales alternating with thin to medium-bedded argillaceous sandstones, the shales predominating.	18	.....
	Top of the Buena Vista member and also the top of the stone quarried. Even-bedded argillaceous sandstones, "free-stones," with thin partings of blue argillaceous shales. The sandstones contain *Taonurus*. The layers are mostly medium-bedded, that is of proper thickness for commercial use. Their size together with the shaly partings render them easily quarried. They are quite extensively worked and make a beautiful and excellent stone	25½	.....
	Soft blue, argillaceous shales with three or four shaly sandstone partings, which contain *Taonurus*	4½	.....
	Soft, blue argillaceous shales	7	.....
3.	**Sunbury shale,** total thickness	.....	16¼
	Black, fissile, carbonaceous shale.		
2.	**Bedford-Berea, total thickness**	.....	18½
	Soft, blue argillaceous and finely arenaceous shales, and fine-grained shaly sandstone. The lower two feet have one or two layers of black, fissile shale	.....	.....
1.	**Ohio shale**	.....	20¾
	Black, fissile, carbonaceous shales	2	.....
	Covered to the level of the Chesapeake & Ohio Railway. Exposures in a nearby gully and in the main stream show, however, that all of this interval is Ohio shale	18¾	.....

A few hundred yards east of Rockville station, the highway crosses the track and a spur extends from the main line to the mill of the Kentucky Bluestone Co. At the spur, the railroad made a slight cut which gives the following section.

SECTION AT THE ROCKVILLE STATION SPUR.

		Feet
2.	**Sunbury shale**	11½
	Black, fissile, carbonaceous shale, to the top of exposure but not of the formatiom.	
1.	**Bedford-Berea shale**	21
	Blue, argillaceous and arenaceous shales with shaly, sandstone partings. The partings are apparently ripple marked. To base of exposure at track level, which must be near the contact with the Ohio Shale.	

A comparison of the last three sections shows that the Bedford-Berea has a thickness of twenty-five, eighteen and one-half, and twenty-one feet for the respective sections. The interval is thin when compared with either the Alum Rock section or the Petersville section. When compared with the Fox Springs section, on the other hand, the rate of decline is seen to be much more gradual than it was in the first half of the journey to the southwest. Sections, reaching as far southward as the Kentucky river, which will follow later, will show that the rate of decline will continue to be gentle.

In the Kentucky Bluestone Company's quarry nearly nineteen feet of the upper Buena Vista stone is quarried. These nineteen feet are even-bedded sandstones with shaly partings and can be correlated with those along the highway ditch. A section of the quarry will be given under the economic division.

There has been some question as to which horizon these sandstones quarried about Farmers belong. Hoeing[12] has referred them to the Berea grit. Foerste[13], judging from the sandstone exposures at Berea and not from personal observations at Farmers, says they probably occur in the upper part of the Waverlian series, three hundred and fifty feet above the base of the series. By referring to the Freestone and Rockville sections they will be seen to belong to the Buena Vista member of the Cuyahoga formation. The member has, however, decreased in thickness from sixty feet along the Ohio river west of Portsmouth to thirty-seven at Rockville. Otherwise they are the typical even-bedded sandstones with shaly partings.

Owing to the southeasterly dip and the rise in the valley the formations rapidly pass beneath drainage between Rockville and Morehead. At the residence of C. W. Bailey, one mile above Rockville, the Sunbury shale has reached flood plain and track level. A few hundred yards still farther east the lower sandstones of the Buena Vista approach track level. And at Brady, one mile below

12. Loc. Cit.

13. Foerste, A. F. "The Silurian, Devonian and Irvine Formations of East-Central Kentucky," Ky. Geol. Surv. Bull. 7, p. 266, 1906.

Morehead, the Buena Vista has passed beneath the C. & O. Railway tracks.

Morehead.—Near the center of Rowan county, is located the county seat, Morehead. The Buena Vista sandstones were just said to pass beneath track level one mile below Morehead. Hence the formation here should be the remaining portion of the Cuyahoga and the representatives of the Black Hand and Logan. Just east of the town is a high hill of upper Waverlian rocks capped by enormous blocks of Lower Carbonic limestone. The barometer gave five hundred and thirty feet for the Waverlian sandstones, the greater portion of which was covered, and seventy feet for the blocks of limestone and overlying sandstone.

A small anticline, normal to the stream, just opposite the depot, brought up a few layers of sandstone which probably belong to the top of the Buena Vista. If the base of these massive blocks lie at approximately the contact and if the barometer registered approximately correct, then these five hundred and thirty feet become very important. If the seventy feet from the base of the Bedford-Berea to the top of the Buena Vista be added to them a thickness of six hundred feet for the total Waverlian is the result.

The Flemingsburg-Morehead highway crosses quite a hill just west of the latter place. On the west side of this hill the rocks are fairly well exposed, especially in the upper part of the section. By beginning well down in that branch of the road which turns off to Rockville the top of the Buena Vista may be taken as a base. From here to the top of the hill in the highway the interval is one hundred and seventy-four feet. Of this amount the lower sixty-five are practically all covered. The remainder consist of light colored argillaceous sandstones and shales.

At Morehead and along Triplett creek valley to the east massive sandstones are shown at about one-third or one-half of distance from the Buena Vista to the Lower Carbonic limestone. At this horizon the sandstones are more indurated and without such distinct bedding planes. They may represent the Black Hand horizon, but their limits probably cannot be determined and probably also shift either upward or downward.

Haldeman.—At Haldeman the massive sandstones mentioned above approach the track level. Here the upper Waverlian is abundantly fossiliferous. The Kentucky Fire Brick Company has a plant here. They get the fire clay fifteen or twenty feet above the Lower Carbonic limestone, which is said to be only four feet in thickness.

East of Haldeman at the county line the Chesapeake & Ohio Railway passes through a long tunnel. At either end of the tunnel is a long cut in the upper Waverlian. In these cuts the rocks are beautifully exposed.

Passing to the extreme western part of the county, there is a poor exposure where the Salt Lick-Plummers Landing highway crosses the point of the county. It shows parts of the Ohio, Bedford-Berea, Sunbury and Buena Vista. The Buena Vista forms the very top of the hill.

CARTER COUNTY.

Carter county lies southeast of Lewis and northeast of Rowan county. Rocks of coal measures age form the surface outcrops of practically the whole of the county. The only exceptions are the narrow belts along those streams which have cut deep valleys, the most important of which is Tygarts creek.

Deep Cut.—At the Lewis-Carter county line the Carter branch of the Chesapeake & Ohio Railway passes from Kinniconick drainage system to that of Tygarts creek. This passage is by means of a cut known as Deep Cut. In the cut twenty-eight and a half feet of the upper Waverlian are exposed. They are thin bedded argillaceous sandstones alternating with shales. Above are seventy feet of Lower Carbonic limestones. Between the two are nearly ten feet of red argillaceous shales or fireclays, the geological position of which has not been determined.

Carter.—In the north central part of Carter county is the small town of the same name. It is the present terminus of Carter branch of the Chesapeake & Ohio.

Here about ninety feet of the Lower Carbonic limestone is quarried for the railroad crusher. From creek level to the base of the limestone there is an interval of two hundred and twenty-five feet. Although mostly covered, it is sufficiently exposed to show that it belongs to the upper Waverlian.

Lawton.—On the Lexington division of the Chesapeake & Ohio Railway about half way between the county line tunnel and Olive Hill, is the small station of Lawton. This locality is near the headwaters of Tygarts creek, but the stream has cut sufficiently deep to expose a hundred feet of the upper Waverlian series. Above this, about fifty feet of Lower Carbonic limestone is quarried for the crusher. Just above the limestone, nearly thirty feet of quartzose sandstone is quarried for glass sand. Both quarries are operated by the Lawton Sand and Supply Co.

BATH COUNTY.

Bath county lies west of Rowan and southwest of Fleming county. The surface rocks of most of the county are of Ordovicic age. However, along the southeastern border there is a narrow belt of Waverlian rocks.

Salt Lick.—On the Chesapeake and Ohio Railway a few miles west of Farmers, is the small town of Salt Lick. The Licking River (narrow gage) Railway runs from Salt Lick in a southeasterly direction, crossing Menefee and entering Morgan county. The following section was made along this narrow gage railroad one mile east of Salt Lick.

LICKING RIVER RAILWAY SECTION, EAST OF SALT LICK.

	Feet	Feet
4. Cuyahoga formation	.....	108½
Brownish, argillaceous and arenaceous shale to the summit of the railway but not of the hill	11	.....
Layer of argillaceous, blue sandstone	5/12	.....
Bluish, argillaceous shale	5/6	.....
Nodular, ferruginous layer	¼	.....
Bluish, argillaceous shale	20½	.....
Layer, blue, argillaceous sandstone	½	.....
Mostly exposed, light, argillaceous shales	12½	.....
Slightly ferruginous, nodular layer	¾	.....
Soft, blue, argillaceous shales with an occasional nodular, ferruginous layer	21	.....
Interval covered	10¾	.....
Layer of argillaceous sandstone, probably the top of the **Buena Vista member.** This and the following layers apparently in position. Dip not computed	2	.....
Soft, blue, argillaceous shale with nodular-like, more arenaceous partings and with some iron	21	.....
Layer of blue, argillaceous shale	⅔	.....
Soft, blue, argillaceous shale	3 5/6	.....
Layer of bluish argillaceous sandstone. *Taonurus*	7/12	.....
Parting of shale	1/6	.....
Layer of bluish, argillaceous sandstone. *Taonurus*	½	.....
Soft, bluish, argillaceous shale	1¼	.....
3. Sunbury shale, total thickness	.....	14½
Black fissile, carbonaceous shale.		
2. Bedford-Berea shale	.....	15
Bluish, argillaceous and arenaceous shales, partly covered. The interval may be 2 or 3 feet more due to the dip	13	.....
Black carbonaceous shale	¼	.....
Bluish, argillaceous, and arenaceous shale	1¾	.....
1. Ohio shale.		
Black, fissile, carbonaceous shale, not measured.		

Caney Switch.—A few miles east of, and on the opposite side of the hill from the last section, is Caney Switch. On the north side of the valley from the switch the rocks are more or less exposed from the Bedford-Berea to the Buena Vista.

The exposures are not all that could be desired but the section will be given for reasons that will be discussed later.

CANEY SWITCH SECTION.

	Feet	Feet
3. **Cuyahoga formation**	.....	55½
Interval covered to top of hill, except some sandstone fragments	36	.....
Layer of argillaceous sandstone	⅔	.....
Covered	1⅙	.....
Layer of argillaceous sandstone	1	.....
Layer of argillaceous sandstone	1 1/12	.....
Shaly parting	⅔	.....
Argillaceous shale	1⅙	.....
Layer, blue, argillaceous sandstone	1¼	.....
Shaly parting	¼	.....
Layer, blue, argillaceous sandstone	1½	.....
Shaly parting	⅙	.....
Layer, blue, argillaceous sandstone	2	.....
Interval covered to the top of the Sunbury, probably shale	7¾	.....
2. **Sunbury shale**	.....	10½+
Black, carbonaceous shale, real thickness not determined, but 10½ feet exposed at another place.		
1. **Bedford-Berea**	.....	19½
Mostly exposed, argillaceous and arenaceous shale, to base of exposure	.....	.....

The last two sections are not over a mile or two miles apart. The important thing is the greater development of the sandstones of the Buena Vista in the section farther east. The number of layers is not much greater, but the thickness of the individual layers is markedly greater. This illustrates a tendency, prevalent at most of the exposures, of the formations to thin in a direction west of the general southwesterly trend of the strike.

School House.—Near Ragland is an Oil Pumping Station, and half a mile below this is a country school house. The dip has been sufficient to bring the Sunbury shale below track level. Beginning under the Licking River Railway trestle the following section was made, up a small ravine near the school house.

SCHOOL HOUSE SECTION.

	Feet	Feet
2. Cuyahoga formation	.....	$5\frac{7}{12}$
Layer of blusih, argillaceous sandstone	$\frac{1}{2}$	.....
Layer of bluish, argillaceous sandstone	$\frac{1}{2}$	.....
Bluish, argillaceous, and arenaceous shales	$2\frac{5}{6}$	.....
Interval covered, to the apparent top of the Sunbury	$1\frac{3}{4}$	.....
1. Sunbury shale	.....	$16\frac{1}{2}$
Black, fissile, carbonaceous shale, the upper half partly covered to base of exposure.		

Half a mile farther east of the Oil Pumping Station the thick bedded Buena Vista sandstones are sharply inclined. This causes the top to pass beneath the Licking River Railway. It also brings them near the mouth of the wells at this place.

Olympian Springs.—Southwest of Salt Lick five miles, is Olympian Springs. In this region the Bedford-Berea, Sunbury, and a portion of the Buena Vista are shown above the Ohio shale. Three sections were made within a radius of a mile of the springs. A hill, one half mile east of the springs, on the road from Olympian Springs to Young Springs, furnished the exposure for the first. The highway leading to the west from Olympian Springs ascends the side of a ridge and descends the other side within a mile. The strata were fairly well exposed on the east and also on the west side of this hill, and furnished the basis for two more sections.

SECTION OF HILL HALF MILE EAST OF OLYMPIAN SPRINGS.

	Feet	Feet
4. Cuyahoga formation	.....	$47\frac{5}{12}$
Mostly exposed, greenish, argillaceous shale to the level hill top. Ferruginous horizon at base	$7\frac{1}{2}$	.....
Mostly exposed, greenish, argillaceous shale	11	.....
Bluish, argillaceous sandstone. *Taonurus*	$1\frac{1}{6}$	.....
Pinkish, and bluish, argillaceous shale with 6 or 8 nodular, ferruginous layers	19	.....
Pinkish, argillaceous shale	$4\frac{3}{4}$	.....
Layer of blue, argillaceous sandstone. *Taonurus*	$\frac{1}{2}$	.....
Soft, blue, argillaceous shale	$3\frac{1}{2}$	.....
3. Sunbury shale, total thickness	.....	$12\frac{1}{3}$
Black, fissile, carbonaceous shale.		
2. Bedford-Berea shale, total thickness	.....	$12\frac{1}{2}$
Soft, blue, argillaceous, and arenaceous shale.		
1. Ohio shale.		
Black, fissile, carbonaceous shale, not measured.		

SECTION OF HILL ONE HALF MILE WEST OF OLYMPIAN SPRINGS.

	Feet.	Feet.
4. **Cuyahoga formation**	.....	27½
Mostly covered, probably argillaceous shale	5½	.....
Blue, argillaceous sandstone, weathering to nodular masses. *Taonurus*	2	.....
Mostly covered, some bluish, argillaceous shale with ferruginous, nodular layers	20	.....
3. **Sunbury shale,** total thickness	.....	12¾
Black, fissile, carbonaceous shale.		
2. **Bedford-Berea shale,** total thickness	.....	5¾
Mostly covered, some soft, argillaceous and arenaceous shale. Both contacts, however, are shown.		
1. **Ohio shale**	.....	.....
Black, fissile, carbonaceous shale, exposed at intervals from near the springs to near to top of the hill. Not measured.		

SECTION OF THE WEST SIDE OF HILL ONE MILE WEST OF OLYMPIAN SPRINGS.

	Feet	Feet
6. **Cuyahoga formation**	.....	12¾
Layer of bluish, argillaceous sandstone, which weathers into nodular masses (covered above)	2¼	.....
Mostly covered, some soft blue, argillaceous shale	10½	
5. **Sunbury shale**	.....	12
Black, fissile, carbonaceous shale.		
4. **Bedford-Berea shale,** total thickness	.....	1/6
Bluish, argillaceous shale.		
3. **Ohio shale,** total thickness	.....	93‡
Black, fissile, carbonaceous shale, to the foot of the steeper portion of the hill (leveled)	48	.....
The barometer gave 45 feet from here to the base of the black shales three-quarters of a mile westward, at Blue Bank creek. The lower part has some soft, blue, argillaceous shale alternating with the black, and is suggestive of the Olentangy shale of central Ohio. Total	45	.....
2. **Devonian limestone**	.....	3⅔
Layer of brownish limestone, Duffin layer	⅔	.....
Two medium layers of brown limestone	1	.....
Layer brownish limestone with chert at the top. Ambocoelia umbonata (Conrad) abundant	2	.....
1. **Crab Orchard shale.**		
Soft, blue, argillaceous shale. Not measured.		

These three sections are given to show the variations in the Bedford-Berea. From Fox Springs to Salt Lick the decrease in thickness has been very gradual, declining from thirty-two and a half at the former to fifteen feet at the latter place. Here at Olympian Springs, on the other hand, we have a decline from twelve and a half, on the east, to five and three-fourths, a mile further west, and to one-sixth of a foot, a half mile farther west. The Sunbury shale, on the other hand, shows little variation in these three sections, being twelve and a half, twelve and three-fourths, and twelve feet in the respective sections. This constancy in thickness on the part of the Sunbury and the proximity of sections leave little doubt that the two-inch horizon in the third section represents the Bedford-Berea. This determination greatly adds in the tracing of the horizon far to the southwest, until the lithological results are confirmed by paleontological evidence.

MENEFEE COUNTY.

Menefee county lies south of Bath and southwest of Rowan. Most of the county is covered by Coal Measure rocks. A belt of Lower Carbonic strata extends along the western side of the county, one along the Licking drainage system on the north, and one along Red River drainage system on the south.

Within the county the Waverlian rocks are exposed at places along the railway which runs from Mt. Sterling to Rothwell. No exposures, however, were sufficient to give a good section. In the highway from Rothwell to Frenchburg a few feet at the top of the Waverlian series were exposed beneath seventy-two and a half feet of Lower Carbonic limestone.

MORGAN COUNTY.

Morgan county lies east of Menefee and southeast of Rowan county. Pennsylvanian strata form the surface rock of practically all of the county. The only exception is in the northwestern part of the county. Here the Mississip-

pian rocks outcrop for a short distance in the valley of Licking River.

A section at Lime Kiln Point, six miles above Paragon, gave over one hundred and fifty feet of Sharon (Coal Measures) conglomerate, seventy-five feet of Lower Carbonic limestone, and sixteen feet of Waverlian. The Waverlian rocks are bluish, argillaceous sandstones and shales. In the upper part of the series there are a few limestone lenticular layers, evidently indicating a struggle for supremacy between the calcareous and argillaceous materials.

MONTGOMERY COUNTY.

Montgomery county lies southwest of Bath and west of Menefee. Ordovicic rocks cover most of the county. Mississippian rocks, however, outcrop along the southeastern border of the county.

Jeffersonville.—About eight miles southeast of Mt. Sterling, is the small village of Jeffersonville. Slate creek has cut its valley into the Ohio shale for quite a distance east of Jeffersonville. This prong of Ohio shale, in a region otherwise exclusively of Mississippian rock, gives a basis for a number of sections extending into the lower Waverlian series.

On the Frenchburg-Jeffersonville highway about half way between the county line and Jeffersonville, and about two and a half miles east of Jeffersonville, a road is given off to the south. Just west of the forks the main road crosses a small run. Here a part of the Sunbury and a part of the Buena Vista are exposed, and the following was made.

SECTION (A) OF RUN TWO AND A HALF MILES EAST JEFFERSONVILLE.

		Feet	Feet
2.	**Cuyahoga formation**	.....	25¾
	Soft, blue, argillaceous shales with four or five nodular, ferruginous layers	13¾	.....
	Covered interval, but apparently shale	4	.....
	Blue, compact, calcareous sandstone, apparently in two layers. These layers break up into flat, nodular pieces and the lower one forms a sort of ferruginous shale at the base. Position of "City ledge"	3⅔	.....
	Soft, blue, argillaceous shale	4⅓	.....
1.	**Sunbury shale**	.....	3⅓
	Black, fissile, carbonaceous shale, the base not exposed.		

The gradient of the above run is large. In passing down stream a short distance the stream has penetrated the Ohio shale. The following (B) section was made about three hundred yards below the last (A) section.

SECTION (B) OF RUN TWO AND A HALF MILES EAST OF JEFFERSONVILLE.

	Feet	Feet
3. **Sunbury shale** Black fissile, carbonaceous shale. The rocks are not exposed above.	.....	10
2. **Bedford-Berea shale,** total thickness Blue, argillaceous shale with some ferruginous material.	.....	4 5/6
1. **Ohio shale** Black, fissile shale, to base of exposure.	....	18 1/2

About a half mile south of the Frenchburg-Jeffersonville highway the branch road mentioned above crosses a small gully. Parts of the Bedford-Berea, Sunbury, and Buena Vista rocks are exposed here. They gave the following section.

SECTION (C) OF GULLY TWO AND A HALF MILES EAST OF JEFFERSONVILLE.

	Feet	Feet
3. **Cuyahoga formation** Bluish or brownish sandstone, probably calcareous. Weathers into large, flat nodules. Position of "City ledge" Interval covered Soft, bluish green, argillaceous shale	.....	10 1/2
	4 1/4	.....
	5 1/4	.....
	1	.....
2. **Sunbury shale,** total thickness Block, fissile, carbonaceous shale.	....	8 3/4
1. **Bedford-Berea shale** Soft, blue, argillaceous shale, base not exposed.	.....	3/4

A little over a mile east of Jeffersonville the Frenchburg-Jeffersonville highway crosses Slate creek by means of an iron bridge. On the hill just east of the bridge the

Bedford-Berea shale and the Buena Vista member are exposed above the Ohio shale. In the steep bank below the road the following section was made.

SECTION AT SLATE CREEK BRIDGE, JEFFERSONVILLE.

	Feet	Feet
4. **Cuyahoga formation**	.....	5 1/2
Layer of massive, argillaceous sandstone. *Taonurus* abundant. Position of "City ledge"	2 5/6	.....
Soft, argillaceous shale	2 1/4	.....
3. **Sunbury shale,** total thickness	.....	11
Black, fissile, carbonaceous shale.		
2. **Bedford-Berea shale,** total thickness	.....	4 1/6
Bluish to dark, argillaceous shale, slightly ferruginous.		
1. **Ohio shale**	.....	31 1/2
Black, fissile, carbonaceous shale, to the base of exposure	31 1/2	.....
Black shales extend to the level of State creek at the bridge, but these were not measured.		

Three or four miles southwest of Jeffersonville the highway forks. One branch goes to Levee and the other to Clay City. Near the forks the following section was made.

SECTION OF LEVEE-CLAY CITY FORKS, JEFFERSONVILLE.

	Feet	Feet
4. **Cuyahoga formation**	.....	4 7/12
Layer of bluish, compact, calcareous sandstone. *Taonurus*.	1 1/12	.....
Partly covered, some soft, argillaceous shale. May contain the contact with the Sunbury shale	3 2/3	.....
3. **Sunbury shale**	.....	6 1/2
Black, fissile, carbonaceous shale.		
2. **Bedford-Berea shale,** total thickness	.....	2 1/6
Bluish, argillaceous shale, slightly ferruginous.		
1. **Ohio shale**	.....	38
Black, fissile, carbonaceous shale, to base of exposure, but not to base of the formation or of the hill at Brush creek.		

In reviewing the sections of Bath and Montgomery counties some important things are brought out. From

Olympian Springs southwestward, at least on the western border of the Cuyahoga outcrops, the sandstone layers of the Buena Vista member begin to gradually disappear. By the time the vicinity of Jeffersonville is reached, only a single layer remains. This layer occupies the position of the lowest, but whether or not it is one and the same layer of different layers at the various exposures to southward cannot be determined. From its position in these sections, it will be seen to occupy the position of the "City ledge."

"West of the Licking River," Hoeing says, "the Berea grit has almost entirely disappeared. To the south it shows, very thin and patchy along the L. & E. Railroad, above Clay City, but was not seen at all in Estill county, and that may prove to be its extreme southern limit."[14] The present authors made no section at Clay City. A section was made, however, on either side, at Indian Fields and at Stanton. In these two it will later be seen that the Bedford-Berea horizon contains no sandstone. It will also be recalled that at this horizon no sandstones are found in the sections south of Petersville. Since there is no Berea grit south of Petersville, then, the thinning attributed to it, south of the Licking river, must be that of the Buena Vista sandstones.

In place of the Buena Vista sandstones, soft, argillaceous shales occur in the lower Cuyahoga. To these clayey shales, Foerste[15] applied the term "Linietta clay," provisionally, before their identity with the New Providence shale of southern Indiana was ascertained. The New Providence shale with the overlying Riverside sandstone, it will be recalled, make up the Knobstone formation of Indiana.

CLARK COUNTY.

Clark county lies to the southwest of Montgomery County. The geological maps show that the rocks of the county are all older than the Mississippian with the excep-

14. Loc. cit.
15. Op. cit. pp. 14, 15.

tion of a fraction of a mile in the extreme eastern corner. Some of the hills are sufficiently high for the black shale to include a part of the Sunbury.

Indian Fields.—On the Lexington & Eastern Railway near the Clark-Powell county line, is the station of Indian Fields. East of and parallel with the railroad is a highway extending from Copperas creek to the Indian Fields-Kiddville highway. Along this road, on top of the hill and about a quarter of a mile from Oil Springs the two following sections were measured.

SECTION (A) AT INDIAN FIELDS.

	Feet	Feet
3. **Sunbury shale** Black, fissile, carbonaceous shale, to the top of the hill.	.....	9¼
2. **Bedford-Berea shale,** total thickness Argillaceous shale.	.....	1/6
1. **Ohio shale,** measured Black, fissile, carbonaceous shale Argillaceous shale Remainder of black shale not measured.	..... 1 1/2 1/6	1 7/12 ....

SECTION (B) AT INDIAN FIELDS.

	Feet
3. **Sunbury shale** Black, fissile, carbonaceous shale.	6½
2. **Bedford-Berea shale,** total thickness Argillaceous shales and shaly limestone. Fossiliferous.	¼+
1. **Ohio shale.** Black, fissile shale, not measured.	

The Bedford-Berea contains, according to Foerste, the following forms:

1. Nuculana sp.
2. Cypricardella (Microdon) sp.
3. Nuculana Kentuckiensis. Foerste.
4. Schizodus spc.
5. Chonetes spc.
6. Camarotoechia spc.
7. Orbiculoidea sp.
8. Camarotoechia Kentuckiensis. Foerste.
9. Schuchertella herricki. Foerste.[16]

POWELL COUNTY.

Powell county lies south of Montgomery and Southeast of Clark county. Red river and its tributaries have removed the more recent strata of the county to such an extent that the black shales and Mississippian strata project far within the area of Pennsylvanian rocks. This leaves but a small belt of Pennsylvanian rocks along the northern eastern and southern border of the county.

Stanton.—Located upon Red river and the Lexington & Eastern Railway near the center of the county, is Stanton, the county-seat. Near the iron bridge in the northern edge of town, Morris creek enters Red river from the north. The following section was taken in the Morris creek highway about a mile north of the iron bridge.

MORRIS CREEK SECTION.

2. **Cuyahoga formation**	.....	22¾
Blue, argillaceous shales with layers of ferruginous nodules..	16½	.....
Nodular layer of bluish, compact, calcareous sandstone.		
Position of "City ledge"	2½	.....
Bluish, argillaceous shales	3¾	.....
1. **Sunbury shale**	.....	4
Black, fissile, carbonaceous shale, to base of exposure.		

About two miles farther up Morris creek, is Morris Mountain. From the "City ledge" to the foot of the mountain the barometer gave an interval of one hundred feet. This is mostly covered. Where exposed, however, it con-

16. Foerste, Aug. F. "The Bedford Fauna at Indian Fields and Irvine Kentucky." Ohio Naturalist, Vol. IX, pp. 515-523, 1909.

sists of argillaceous and arenaceous shales. In the lower part of the mountain is a long mostly covered interval of three hundred and seventy feet, according to the barometer. The few exposures in this interval also consists of arenaceous shale. The next twenty-four feet are massive, argillaceous, buff sandstones with shaly sandstones between, and slightly covered. Above are thirty-nine and a half feet of similar massive sandstones without apparent bedding planes, and which break up into thin shaly parts on weathering. The next interval of sixty-seven feet reaches the Lower Carbonic limestone, and is practically covered except some shales with two or three thin layers of sandstone. Assuming the two intervals making four hundred and seventy feet, measured by the barometer, to be correct and adding the three extra feet, exposed in the next section, to the base of the Waverlian we have a total thickness of six hundred and thirteen and three-fourths feet for the series. This agrees very closely with the complete thickness of the series at Morehead, where it was computed to be six hundred feet.

From the Waverlian series to the top of the hill there is an interval of over a hundred feet. It is mostly covered. Where exposed, however, the rocks are limestones of Lower Carbonic age. The upper part contains blocks of light, gray limestone, while the limestone in the lower part turns yellow when subjected to the elements.

Along the north wall of Red river valley a short distance west of Morris creek and about one mile northwest of Stanton, is the residence of Lewis Faulkner. Leading up the bank from the main road to the house there is a lane. Along this the following instructive section was measured.

SECTION AT LEWIS FAULKNER'S.

	Feet	Feet
4. Cuyahoga formation	.....	4¼
Soft, blue, argillaceous shale, not measured.		
Layer of buff, fine-grained, calcareous sandstone, which weathers into large, flat nodules. Position of "City ledge"	1¼	.....
Soft, blue, argillaceous shale	3	.....
3. Sunbury shale, total thickness	.....	6½
Black, fissile, carbonaceous shale.		
2. Bedford-Berea shale, total thickness	.....	7/12
Bluish, argillaceous and calcareous shales.		
1. Ohio shale	.....	16½
Black, fissile, carbonaceous shale	16½	.....
Covered to highway	19¾	.....

ESTILL COUNTY.

Estill county lies south of Powell and Clark counties. As the Red river in Powell county removed the younger strata, leaving exposed the Mississippian and older rocks over most of the county, so also has the Kentucky river performed a like task in Estill county. The result is an area of Mississippian strata projecting for quite a distance into a Pennsylvanian area.

Irvine.—Irvine is the county seat and is located near the center of the county on the Kentucky river and on the Louisville and Atlanta Railway. In the eastern end of town there is a high hill known as "Minerva Mountain." The strata are more or less exposed from the Ohio shale to the Lower Carbonic limestone, upon the side of the mountain, and here the following section was made.

SECTION OF MINERVA MOUNTAIN.

	Feet	Feet
6. Sub-Carboniferous limestone	.....	1
Yellowish, sandy-like limestone, lying at the extreme top of the hill.		
5. Upper Waverlian series, not divided	.....	344
Covered interval	60½	.....
Thin bedded, buff, argillaceous sandstones, which weather to thin shaly pieces, *Taonurus*	17	.....
Layers of massive, buff, argillaceous sandstone, *Taonurus* abundant	24	.....
Buff, argillaceous sandstones, weathering to shales. *Taonurus*	17	.....
Covered interval	225½	.....

SECTION OF MINERVA MOUNTAIN—Continued.

	Feet.	Feet.
4. **Cuyahoga formation,** top not determined.....	.....	144
Brownish, ferruginous, and calcareous, nodular layer of sandstone.....	½	.....
Indurated, bluish to pinkish, argillaceous shales with ferruginous, nodular layers.....	69½	.....
Soft, bluish, argillaceous shale with ferruginous, nodular layers, slightly covered (top of Linietta clay).....	63½	.....
Layer of brownish, argillaceous sandstone, which breaks up into shaly layers. Position of "City ledge".....	2	.....
Soft, bluish to pinkish, argillaceous shales with small phosphatic nodules.....	8½	.....
3. **Sunbury shale,** total thickness.....	.....	3
Black, fissile, carbonaceous shales.		
2. **Bedford-Berea,** total thickness.....	...	1½
Argillaceous shales with phosphatic nodules.....	⅙	.....
Black, fissile, carbonaceous shales.....	¼	.....
Dark, argillaceous shales, with some carbonaceous material.	½	.....
Gray, calcareous, and argillaceous shales, slightly fossiliferous	⅙	.....
Yellowish, calcareous, and argillaceous shales, the upper part very fossiliferous.....	5/12	.....
1. **Ohio shale**.....	.....	94½
Black, fissile, carbonaceous shales, with an occasional softer argillaceous layer. Practically all exposed to the highway.		

The following fossils were collected in the Bedford-Berea.

1. **Schuchertella morsei.** Foerste.
2. **Ambocoelia norwoodi.** Foerste.
3. **Lingula irvinensis.** Foerste.
4. **Orbiculoidea spc.**
5. **Macradon hamiltoniae-irvinensis** (variety). Foerste.[17]

Of this list Macrodon hamiltoniae is common in the Bedford-Berea of Kentucky and in the Bedford at Columbus, Ohio. Furthermore, if Foerste's paper cited above be studied or if the specimens from the two States be compared the close relationship of the Kentucky Bedford-Berea fauna with that of the Ohio Bedford will be clearly seen.

In this connection, it might be well to give the conclusions reached by Professor Williams in his paleontological

17. Loc. Cit.

study of the black shales. He states that an "examination of the section at Irvine, Kentucky, the other side of the Cumberland channel revealed the fact that there the black shales were thinner but held on in their purity, well up into Carboniferous time. The intercalations consist of calcareous and ferruginous, concretionary sheets, and carry undoubted Carboniferous fossils and occur in the sections before the black shale loses its characteristic expression."[18]

These black shales have been correlated with the Ohio black shale in the various geological reports of the State. The geologists of the Federal Survey, approaching the field from the south, have, on the other hand, designated them as the Chattanooga shale.[19] Both have referred them, in their entirety, to the Devonic system. That they belong to both the Devonic and Carbonic systems, has, it is thought, been clearly demonstrated.

In the London and Richmond Folios of the U. S. Geological Survey, Campbell has designated the clay shales and argillaceous sandstones, above the Black shale, as the Waverly formation. It is permissible, according to the rules of that survey, to reduce a series to the rank of a formation, but, as applied here, Waverly covers not more than the upper half of that division. The lower half, Bedford-Berea, and Sunbury, has just been shown to be included within the limits of the Chattanooga (Ohio) shale.

It is interesting to note that Grabau anticipated this limitation. Referring to the London Folio, he states that: "The shale above the Black (Ohio) shale is referred to the Waverly, of which it probably constitutes the upper portion only. As at Irvine, the transition from the Black shale to the overlying beds is probably a gradual one."[20] This conclusion seems to have been reached deductively, from a

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18. Williams, Henry S., On the Southern Devonian formations, Am. Jour. Sci., 4th series, Vol. III, p. 398, 1897.

19. Estillville, London and Richmond Folios, U. S. Geol. Suv. (No. 12, 1894; Nos. 46 and 47, 1898.)

20. Grabau, Amadeus W., "Types of Sedimentary Overlap", Bull. Geol. Soc. Am., Vol. XVII, pp. 609, 610, 1906.

study of Williams' paper which he quotes and to which reference was made above.

SUMMARY.

The Bedford and Berea formations thin rapidly southwestward from the Ohio river, and this horizon, even after it has been reduced to a thickness of only a few inches, can be traced to near the crossing of the Cincinnati geanticline by the Waverlian series.

The Sunbury shale, on the contrary, suffers but litle decline, at least until Indian Fields is reached.

The Ohio black shale of the Kentucky reports, or the Chattanooga shale of the U. S. reports, south of Petersville is not of Devonic age alone, but of Devonic and Carbonic, that is, is composed of both the Ohio and Sunbury shales, and a thin zone representing the Bedford and Berea.

The sandstones which are extensively quarried about Rockville Station belong to the Buena Vista member of the Cuyahoga formation rather than to the Berea grit or higher rocks of the Cuyahoga.

The Buena Vista sandstones begin to disappear from Olympian Springs southwestward except a single layer, which if not always the same, at least occupies the position of the lowest ("City ledge") and which persists as far south as Stanton if not to Irvine.

The Linietta clays belong to the lower part of the Cuyahoga formation.

The so-called Waverly of at least the Richmond Folio includes only the upper part, beginning with the base of the Cuyahoga.

PART II.

ECONOMIC GEOLOGY.

A discussion of the Waverlian formations of East-Central Kentucky would not be complete without mentioning their economic importance. Especially is this true of the building stone and the oil and gas resources. The shales could also possibly be made the basis of quite a ceramic industry, if not also of a cement industry. The building stones will be discussed first.

BUILDING STONE.

Under building stone is grouped all stone for constructional purposes including curbing, flagging, bridge stone and the like. In contradistinction to this term is crushed stone for concrete, ballast, road metal, and other purposes. The building stones of the series are all sandstones and will be taken up by formations.

THE BEDFORD FORMATION.

Attention has already been called to the extensive quarries in the Euclid lentil of the Bedford formation just east of Cleveland, Ohio. The development of a similar lentil in the same formation at Vanceburg has also been pointed out. Alum Rock section shows that nearly forty feet of the middle Bedford contain a number of even-bedded layers of sandstone. These range from thin or medium layers to thick layers. They are either separated by thin intervals of shale or by shaly partings. These intervals render them easily quarried and there seems to be no good reason why they could not, under proper conditions of exposure, be used as a building stone. These remarks apply exclusively to Lewis county, however, since the sandstone are wanting from Petersville to the south.

THE BEREA FORMATION.

The Berea grit is the important sandstone of Ohio. In 1907 Ohio ranked third in the production of sandstone in the United States. Of the $1,600,000 produced, the greater part came from the Berea grit. In Ohio, the formation furnished, during the same year, $764,276 of the $896,022 of grindstones and pulpstones or practically half of the natural abrasives of the whole United States.

At Vanceburg there are over twenty feet of the Berea. A good idea of the formation is had by consulting the Alum Rock section and Fig. 4. The sandstone could, no doubt, be quarried successfully under favorable conditions of exposure. The sandstones, like those of the Bedford, are not developed south of Petersville, and hence the surface exposures are also confined to Lewis county.

THE LOWER CUYAHOGA FORMATION.

It is the Buena Vista member of this formation that furnishes the important sandstones of the Waverlian series in this part of Kentucky. The sandstones are fine-grained and argillaceous and work nicely. They occur in even layers between which thin zones or partings of shale are intercalated. This last condition renders quarrying an easy task. Since the Buena Vista is already quarried in west-central Rowan county, this county will be given first.

ROWAN COUNTY.

A reentrant angle in the foot hills of the Alleghany Mountains carries a peneplain to a point a few miles east of Farmers. This peneplain is just above the Buena Vista sandstones. Licking river and Triplett creek, its tributary, have carved their valleys into this peneplain to a sufficient depth to expose the upper portion of the Ohio shale. These natural features combined with good shipping facilities make this a most desirable place to quarry the Buena Vista stone. Three companies have

availed themselves of these natural advantages, and a quarry is located at Farmer; a second at Freestone Station; and a third at Rockville Station.

Rockville Station.—The quarry at Rockville Station is owned and operated by the Kentucky Bluestone Company, This quarry and the one at Freestone were visited. At the Rockville quarry the material of the stripping was not dumped against the quarry face as it was in the Freestone quarry. This favorable condition at the former place permitted measurements to be made for the following section.

SECTION OF THE KENTUCKY BLUESTONE COMPANY'S QUARRY.

	Feet	Inches	Feet
1. **Cuyahoga formation**	.....	.....	37
Layer of blue fine-grained sandstone	.....	10	.....
Soft, blue, argillaceous shale with some thin sandstones intercalated	3	6	.....
Layer of blue, fine-grained sandstone	.....	5	.....
Soft, blue, argillaceous shale	5	6	.....
Layer of blue, fine-grained sandstone	1	.....	.....
Soft, blue, argillaceous shale with two ferruginous, nodular layers at the top	2	2	.....
Layer of blue, argillaceous sandstone	.....	6	.....
Soft, blue, argillaceous shale	1	9	.....
Layer of blue, fine-grained sandstone	.....	4	.....
Soft, blue, argillaceous shale with ferruginous nodules.	2	2	.....
Top of the Buena Vista and also of the quarry-stone ($18\frac{1}{2}'$), layer of fine-grained, blue sandstone with numerous *Taonurus* markings. This description will apply to the following layers and will not be repeated	.....	5	.....
Parting of soft, blue, argillaceous shale. This description also covers the following partings not otherwise described and will also not be repeated	.....	2	.....
Layer of sandstone	.....	$10\frac{1}{2}$	.....
Parting	.....	$1\frac{1}{2}$	.....
Layer of sandstone	1	.....	.....
Parting (Arenaceous)	.....	2	.....
Layer of sandstone	.....	9	.....
Blue argillaceous shale	1	1	.....
Layer of sandstone	1	4	.....
Parting	.....	$\frac{1}{2}$	.....
Layer of sandstone	.....	9	.....
Parting	.....	$1\frac{1}{2}$	.....
Layer of sandstone (with numerous cracks)	1	8	.....
Parting (with a 2 inch layer of sandstone at the top and bottom. Top one ferruginous)	.....	9	.....
Layer of sandstone	1	$5\frac{1}{2}$	.....
Parting	.....	$4\frac{1}{2}$	.....
Layer of sandstone	.....	$7\frac{1}{2}$	.....
Parting	.....	$4\frac{1}{2}$	.....
Layer of sandstone	1	9	.....
Nodular layer of sandstone which gives way to shales	.....	$4\frac{1}{2}$	.....
Parting	.....	$4\frac{1}{2}$	.....
Layer of sandstone	.....	5	.....
Parting	.....	3	.....
Layer of sandstone	1	4	.....
Parting	.....	3	.....
Layer of sandstone, to base of quarry	2	.....	.....
The quarry men say that below are three or four layers of sandstone with considerable amount of shales between. This statement is corroborated in the Rockville Station section where the 6 or 7 feet, directly above the $11\frac{1}{2}$ feet of shales, at the base of the Buena Vista answered the above description.			

Further discussion seems superfluous after the above section has been given, yet attention should again be called to this excellent stone. An examination of Fig. 5, one of the quarries near Farmers, will help emphasize the important points. The eveness of the layers and the various layers of different thickness give a product of most any desired thickness with the least possible expense. The thin shaly intervals also greatly facilitate the quarrying of the stone. The stone was used in the construction of the court-house at Lexington in 1882.

A good idea of some of the building stone that may be quarried from the Buena Vista can be had from examining the list of the Kentucky Bluestone Company of which Mr. J. F. Knapp is President; Mr. W. H. Daniels, Secretary; and Mr. Albert Willet, Assistant Secretary. Among other kinds of stone this company successfully produces the following: Under block stone, mill blocks, bridge stone, and monument bases; under sawed stone, sawed curbing 4 by 18, 5 by 18, and 6 by 18, sawed stone 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12 inches thick, sawed flagging 2, 2½. 3, 3½, and 4 inches thick, also sills, caps, steps, and columns.

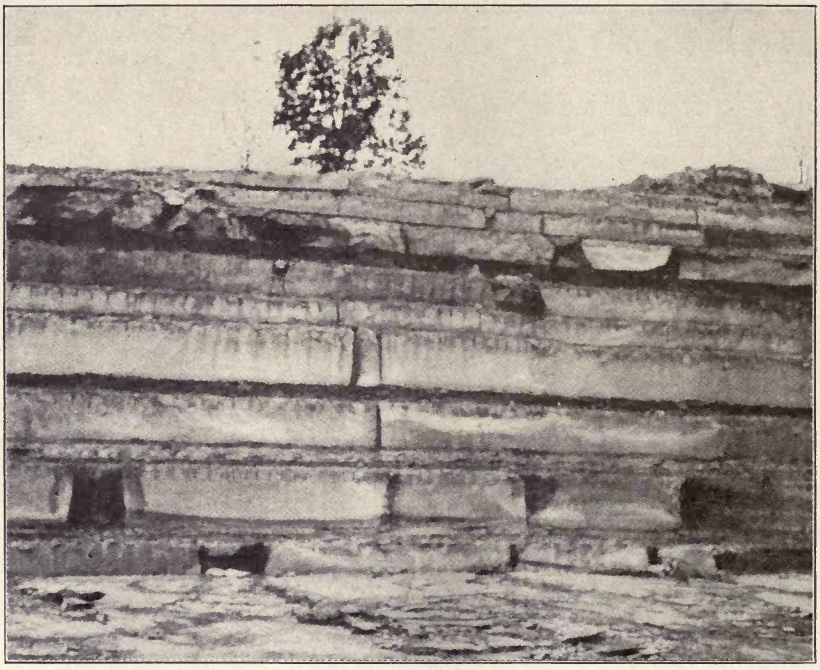

Fig. 5. Buena Vista sandstones. Note the even layers with shaly partings. Near Farmer, Ky.

This same company published the following physical and chemical tests made by the Pittsburg Testing Laboratory, Limited:

PHYSICAL TEST.

"Crushing strength 14030 per square inch. Absorption gain 3.99 per cent."

"Stone was thoroughly dried, then immersed in water 48 hours, then frozen for 24 hours at a temperature of 5 degrees Fahr., then dried for 24 hours, again immersed in water for 48 hours and frozen for 64 hours at a temperature of 5 degrees Fahr., after which stone was thawed out and showed no signs of disintegration or cracks.

CHEMICAL ANALYSIS.

	Per Cent.
Loss of Ignition	2.40
Silica	84.60
Oxide of Iron	1.86
Alumina	7.26
Lime	0.55
Magnesia	0.60
Soda	0.39
Potash	1.94

The above analysis compares very closely with the following one quoted by Foerste.[21]

"2429.—Sandstone. From quarry, the one not stated, near Farmer Station on the Chesapeake & Ohio Railroad, thirty-five miles beyond Mount Sterling. Collected by W. W. Monroe. (Analysis made in laboratory of the Kentucky Geological Survey.)

"Analysis; sample air-dried:

Moisture and loss	2.514
Sand and insoluble silicates	93.128
Alumina, phosphoric acid and loss	1.188
Iron carbonate	2.336
Lime carbonate	.578
Magnesia carbonate	.256
Total	100.000

21. Foerste, Aug. F. "The Silurian, Devonian and Irvine Formations of East-Central Kentucky." Ky. Geol. Surv. Bull. 7, P. 266, 1906.

Freestone Station.—The Kentucky Freestone Company owns and operates the quarry at Freestone Station. By comparing the section at this station with the one at Rockville Station the Buena Vista appears to be ten feet less in thickness. Although most of the quarry face was covered yet enough was exposed to show the nature of the stone. It is the typical even-bedded, fine-grained sandstone with shaly partings. What has been said about the stone at the former place ought to apply here, since the quarries are only a mile or two apart.

Farmer.—[The Rowan County Freestone Company operates a quarry and mill at Farmers. Its plant is well equipped and the excellence of the stone produced is well known. The stone used for the abutments and cental pier of the Chesapeake & Ohio Railroad bridge over the Licking river came from these quarries. The pier presents a striking example of the superior quality of the Buena Vista stone as developed in Rowan County. —C. J. N.[21½]]

LEWIS COUNTY.

Slate Point.—At Slate Point, Vanceburg, the sandstones of the lower Cuyahoga are developed for over one hundred and eighty-five feet. This reaches far beyond the limits of the Buena Vista member, and since there is no conspicuous shaly interval and also since the exposure is not very good, the top limit of the member is hard to determine. The sandstones are, however, the same as those of the Buena Vista proper. They are even-bedded with shaly partings or shaly intervals and fine-grained. With this vast thickness of sandstones in the Cuyahoga and with those of the Berea and Bedford developed the sandstone resources of this part of the county are important.

Vanceburg Hill.—The sandstones of the lower Cuyahoga are developed for over a hundred and eighty feet at

21½. For detailed descriptions of quarries in Rowan County and in Lewis, see Report on the Economic Geology of Lewis and Rowan Counties by F. Julius Fohs.—C. J. N.

Vanceburg Hill. By referring to the section of this place it will be seen that seventy-five of the lower one hundred and five feet are excellent quarry stone, while the remaining portion of the section contains a large number of important layers. This enormous development of sandstones ought to make this locality an important center of building stone production. The locality is only three miles from the Chesapeake & Ohio Railway and from the Ohio river.

At Petersville and Esculapia Springs the sandstones of the lower Cuyahoga are excellently developed. The same is probably also true at other places. The sandstone resources of the county are therefore seen to be abundant.

FLEMING COUNTY.

The western edge of the Waverlian rocks form the surface exposures along the extreme eastern edge of this county; so that the county contains some Cuyahoga stone. Fox Springs section shows over thirty feet of Buena Vista sandstone, twenty-five feet above the base of the member. These are the typical Buena Vista sandstones, even-bedded, fine grained with shaly partings. They would make a good building stone.

BATH COUNTY.

Caney Switch.—The section along the Licking River Railway one mile east of Salt Lick shows that the sandstones of the Buena Vista member here begin to disappear. Farther east, however, there are twelve feet of fine stone exposed in the Caney Switch section. There is also a possibility of the covered interval containing more. The close proximity of the exposure to the railroad and to the top of the hill seem to indicate a desirable place for a quarry. The fact, however, that the stone would have to be transferred to standard gage cars at Salt Lick would of course add to the cost of production. Investigation might show the natural advantages to be sufficiently great, though, to counter-balance this.

Olympian Springs.—An examination of the sections about Olympian Springs reveal the fact, that the Buena Vista sandstones have practically disappeared. A few layers remain, though, and the "City ledge" was seen to be quite persistent. These, however, can not be of more than local importance.

THE UPPER CUYAHOGA AND UPPER WAVERLIAN.

Nothing has been said of the sandstones of the upper Cuyahoga and the upper Waverlian. The former may contain sandstones and the latter has been shown to do so. They no doubt are of economic importance, at least in places. No time was spent upon them in this hasty study. They evidently do not contain a large number of layers so conspicuously important as does the Buena Vista.

SUMMARY.

The sandstones of the Bedford and Berea formations are developed in the northern part of Lewis county, but disappear south of this place. They could no doubt be quarried successfully here. The sandstones of the Buena Vista member and in places those just above are the important ones, however. They are successfully quarried in western Rowan county. Since they are developed completely across Rowan and in the adjacent parts of Bath and Fleming counties and to such a thickness in Lewis county, the quarrying operations could be extended almost without limit in this part of the state. It is true that cement has replaced stone to quite an extent, yet there are many uses for which stone will probably never be supplanted to any great degree. Surely the Buena Vista stone could and ought to be used more extensively in the construction of the better dwellings and public buildings. An inspection of the beautiful court-house at Lexington will bear out this statement.

SHALES FOR THE MANUFACTURE OF BRICK AND TILE.

At various horizons throughout the Waverlian series, occur zones of clay shales or more of less purity. There is no doubt that some of these could be utilized for the manufacture of, at least, the rougher wares, such as common brick and drain tile, and possibly for the better grades such as paving brick, face brick, sewer pipe, and roofing tile. These zones will be pointed out in the following discussion. It should always be borne in mind, however, that no capital should be invested until the shales have been given a thorough physical test. This is absolutely necessary and if it were adhered to it would prevent the repetition of investing thousands of dollars only to find the clays or shales were practically useless. According to Professor Orton the value of a clay or shale for ceramic products depends upon its freedom from:

1st. Bituminous matter and sulphur in the form of iron pyrites ($Fe S_2$).

2d. Carbonates of lime or magnesia, either in the lumpy or precipitated form.

3d. Intercalated layers of sandstone.

4th. Concretionary iron ore.

With the above understanding and warning the various formations will now be treated in the order of their age. The Bedford and Berea formations will be grouped together however, since they can be separated but for a short distance.

THE BEDFORD AND BEREA FORMATIONS.

The Bedford formation in Ohio is nearly always a clay shale or contains a large proportion of clay shales. In northern and Central Ohio it contains vast deposits of economic value. It has long been used in the manufacture of brick by the Hydraulic Pressed Brick Company and by its predecessor, the Akron Vitrified Brick Company at Independence, in the northern part of the state. Just east of Columbus two plants utilize its material.

In the Vanceburg section the formation was shown to be quite largely intercalated with sandstones. The lower twenty-two feet were practically covered, but showed some argillaceous shales. It is possible that they are clay shales, but to discuss their economic value would be too much of an assumption and should await further study.

At Petersville the sandstone layers of the Bedford and Berea have both disappeared leaving only a shaly interval. This interval contains some arenaceous shales and also some arencaeous and calcareous intercalations. The same conditions exist at Fox Springs, Freestone Station, Rockville Station, Salt Lick, and Olympian Springs. In addition there seems to be some nodular ferruginous material at some of the places. South of Olympian Springs the shales are too thin for use. The outlook for the Bedford-Berea shales, therefore, is not a promising one. The proper tests, however, might show a part of the interval to be of importance.

THE SUNBURY SHALE.

This stratum, like most of the Ohio shale, contains considerable bituminous or carbonaceous matter disseminated throughout the formation. Quite an extensive plant for the manufacture of sewer pipe, etc., at Columbus, Ohio, obtained their raw material from the lighter colored Ohio shale. This plant, however, was always greatly handicapped in its operations and is shut down at the present time. At Delaware, Ohio, the Delaware Clay Company are using a little of the weathered top of the Ohio shale and a thin deposit of overlying Pleistocene clay. Freedom from bituminous matter and sulphur was Orton's first prerequisite for a good ceramic shale and it therefore seems quite probable that the Sunbury shales will not become an important source of raw material.

THE LOWER CUYAHOGA FORMATION.

LEWIS COUNTY.

Vanceburg.—The basal part of the Cuyahoga formation at Vanceburg is more or less covered. There are some argillaceous shales. Whether these are thick enough for

profitable use or not can only be told by further study. The Vanceburg Hill section shows a shaly zone of sixteen and a half feet at the summit of the highway. These shales are somewhat arenaceous. They resemble in appearance those quarried by the Peebles Paving Brick Company east of Portsmouth, and possibly occur at about the same geological horizon. The shaly interval may extend farther up the hill above the highway, and is worthy of investigation.

ROWAN COUNTY.

Rockville Station.—The Rockville Station section gives thirty-three feet of shale in the Cuyahoga formation above the Buena Vista member. The shales are soft, blue, and argillaceous. They contain an occasional ferruginous parting but it is quite probable that the amount is small or that it could be easily removed. Should the physical tests show that this shale is suitable for ceramic purposes it would be an important locality because of its natural advantages. The clay lies just beyond the present operations of the Kentucky Bluestone Company and reaches to the top of the peneplain. The exposure reveals no superjacent material other than the soil. This would reduce the expense of stripping to a minimum. The removal of the shales would also reduce the amount of stripping which the stone company will be compelled to do when they work back farther from the valley. Not least of all is the proximity to a railway line.

[Samples of the shale overlying the stone worked by the Rowan County Freestone Company, at Farmer, were analyzed by the Survey chemist. The analysis indicate their suitableness for brick. See Report on the Economic Geology of Lewis and Rowan Counties.–C.J.N.]

BATH COUNTY.

Salt Lick.—Quite a number of shale zones are shown in the Licking River Railway section taken one mile east of Salt Lick. Thirty to fifty feet of argillaceous shales are exposed along this narrow-gage road. These could be

quarried by removing a very small per cent. of waste material, as the section will reveal. They also seem to be comparatively free from those minerals considered injurious to clay products. If the physical test should reveal a shale suitable for the manufacture of common brick, drain tile etc., the exposures are fairly accessible. They are located near the summit of the narrow-gage road, so that the loaded cars would probably drift by gravity into Salt Lick. Satisfactory arrangement could, no doubt, be made with the Licking River Railway, so that the only expenditure of energy would be in returning the empty shale cars to the quarry. The proposition seems worthy of consideration.

Olympian Springs.—The forty-seven feet of lower Cuyahoga in the first Olympian Springs section reveals the beginning of the end of the Buena Vista sandstones. The removal of the two layers of sandstone and the nodular, ferruginous layers from the argillaceous shales could probably be done with little expense. This would leave a large percentage of argillaceous shales. The same is, also, probably true for the Cuyahoga in the other exposures in this vicinity.

POWELL COUNTY.

Stanton.—Morris creek section at Stanton shows sixteen and a half feet of clay shales above the "City ledge" and, no doubt, more occur in the (mostly) covered interval above. These contain, however, layers of ferruginous nodules. Careful study may show that these nodules are sufficiently large to be removed by machinery and the shales made available for clay products.

ESTILL COUNTY.

Irvine.—The lower one hundred and thirty or forty feet of the Cuyahoga in the Minerva Mountain section at Irvine consist almost exclusively of shales. These contain ferruginous, nodular layers similar to the same horizon at Stanton. Because of the great development of these shales in this region a careful examination should be made to de-

termine the practicality of their utilization. Should the removal of the ferruginous nodules be possible or proven not necessary, it would open up a vast storehouse of raw material. The shales are here in abundance. The authors have called attention to their presence here and at other localities. They have also suggested the possibility of their utilization. Their work should now be supplemented by the proper physical and other tests in order to determine their fitness for the various products.

THE UPPER CUYAHOGA AND UPPER WAVERLIAN.

The strata above the lower Cuyahoga formation contain shales. The brief period in the field did not permit of their study. They possibly contain shale zones of sufficient thickness and purity for ceramic purposes. Their importance must not, in any way, be judged by their scant treatment in this report. After their stratigraphy has been worked out a report of their economic value would be both in order and desirable.

Deep Cut.—Attention has already been called to the ten-foot zone below the Lower Carbonic limestone at Deep Cut, Carter county. Sufficient study has not been made to determine its true geological position. It seems improbable that it will be referred to the Waverlian, yet its economic possibilities will be discussed under this series. The zone is not readily accessible for examination in the steep walls of the cut. However, upon weathering it appears as a red argillaceous shale while in a fresh condition it is like a red fire clay. This clay would, possibly, make a beautiful red front brick, probably of the pressed variety. Its development directly by the side of the railroad is an important factor. Furthermore, the massive Lower Carbonic limestone would make an excellent roof for the mine. Or still better yet the limestone could be quarried for ballast, as it is so extensively done at Carter only a few miles to the east. The limestone quarried at this place would not have to be hauled up the steep grade from Carter to Deep Cut; a grade so steep that it is necessary to double or treble the hill with even a small train load. After the

limestone was removed the shale or clay could be easily won either by hand or steam shovel. This zone ought by all means to receive the proper practical tests.

It must be thoroughly understood that this is but a preliminary report. The data were secured while rapidly tracing the Waverlian formations. Sections were measured only where the exposures were sufficiently great to make the sections of stratigraphical importance. For this reason only a small part of the area has been covered in detail. The economic side of the report must therefore of necessity be meager. It was thought of sufficient importance to publish even this, with the understanding that many other horizons and places of occurrence of shale are probabel.

SUMMARY.

The Bedford formation approaches the Berea formation in the developments of its sandstones in Lewis county. The result is that most of the clay shales, so fully developed in the formation throughout Ohio, are supplanted by sandstones or arenaceous material. It is possible, though, that it may be of value at places within the county.

The Berea in the northern part of the county is a sandstone stratum. Only about one foot of shales occur at the base. Hence the formation has no ceramic value.

The Bedford and Berea horizon, south of Petersville, has not developed sandstones. Arenaceous material is common in the form of arenaceous shales or shaly intercalations. The value of these shales for caramic products is doubtful, but a test may show the opposite to be true.

The Sunbury is a dark carbonaceous or bituminous shale. Since the plants dependent upon the similar Ohio shale have not been the most successful and since freedom from bituminous matter is Orton's first requisite for a good shale, it seems probable that this shale will not become important.

The shales in the lower part of the Cuyahoga formation both in the Buena Vista member and just above it have been pointed out as important. As the sandstones

of the Buena Vista disappear to the southward, the argillaceous shales take their places. The result is a thick deposit which, if they show the proper tests, would become a most valuable source of raw material for ceramic purposes.[22]

SHALES FOR THE MANUFACTURE OF PORTLAND CEMENT.

Ferruginous Shales.—In his chapter on " Raw Materials of the Cement Industry" Bleininger says: "Shales high in ferric oxide are plentiful in Ohio and may give rise to valuable source of cement material..... "As to the influence of the high content of iron in these shales on the cement to be produced, it may be said as long as the content of iron does not run too high, say more than 10 per cent of ferric oxide, the shales are to be preferred to clays lower in iron but higher in alumina, inasmuch as they cause the burning to take place at a much lower temperature and reduce the danger of spoiling the mixture in the burning by dusting. The only possible objection which can be brought against a cement made from ferruginous shale is the darker color, which, of course, is due to high iron content.

"..... it may contain concretions often to the size of a man's head, of ferrous carbonate, which of course are rejected. These kidneys of iron carbonate, if present in large quantities and in smaller lumps so that they cannot be removed by hand or machinery, cause the shale to become worthless for all manufacturing purposes. Another impurity liable to be found is iron sulphide (pyrites) in the hard shale which in the oxidized, softened shale becomes iron sulphate.

"We may say, therefore, that ferruginous shales, provided they are sufficiently low in alumina and magnesia, do not contain too much concretionary iron and are not too hard, are well suited as cement materials. The limit of the ferric oxide content may be placed at 10 per cent."[23]

22. Foerste, A. F., "The Silurian, Devonian, and Irvine formations of East-Central Kentucky." Kentucky Geol. Survey, Bull. No. 7, 1906, p. 262.

23. Bleininger, A. V. "The Manufacture of Hydraulic Cements," Geol. Surv. Ohio, Bull. 3, pp. 74, 76, 1904.

A number of horizons in the Waverlian may contain this desirable shale since a number contain ferruginous material. The one conspicuous horizon of ferruginous shales is, however, the lower Cuyahoga or Linietta clay of Foerste in the southern part of the area under discussion. No chemical analyses of these shales for this region are at hand. Foerste, however, gives a number of analyses from the region to the southwest. (Bul. 7, Ky. Geo. Sur.) Since the analyses show the shales to be fairly constant two of these will be given.

2597.—Analysis of clay. From Blue Lick, Madison county. From Berea, 1.5 miles northeast on Kingston pike, then 1.5 miles east to junction with Blue Lick pike, southwest of road corner. Geological position: From 0 to 40 feet above the base of the Linietta or New Providence clay, in the lower part of the Cuyahoga formation. Collected by A. F. Foerste, 1904.

Analysis of air-dried sample:

	Per Cent.
Moisture	1.75
Ignition (combined water, etc.)	4.29
Silica	63.58
Alumina	16.00
Ferric oxide	5.21
Lime	.03
Magnesia	1.25
Potash	3.89
Soda	.82
Titanium dioxide	1.13
Sulphates and phosphates	Traces
Total	97.95

"2618.—Analysis of clay, Junction City, Boyle county, Ky. Geological position: Linietta or New Providence clay, in the lower part of the Cuyahoga formation; Blue Lick, northwest of Linietta Springs, northwest of Junction City about one-half mile. A. F. Foerste, 1904.

Analysis of air-dried sample:

	Per Cent.
Moisture	1.35
Ignition (combined water, etc.)	4.85
Silica	62.44
Alumina	17.87
Ferric oxide	6.31
Lime	.18
Magnesia	1.18
Potash	3.52
Soda	.77
Titanium dioxide	1.04
Sulphury trioxide	.19
Total	99.70

The localities at which these two samples were taken are about as far from each other as the nearer is from Irvine. The analyses, therefore, may be fairly representative of the shales in this region. If this be true and if it be possible to remove the ferruginous nodules, then the shales evidently would conform very closely to the ferruginous shale described above by Bleininger. They would for this reason, then, be valuable in the manufacture of Portland cemnet.

CARBONACEOUS SHALES.

Speaking of the Carboniferous (carbonaceous) shales, Bleininger further states: "These differ from the other shales in the fact that they contain carbonaceous matter varying from one or two to 12 or 14 per cent. The most prominent shale of this type is the Huron (Ohio) shale, of Devonian age, lying on top of the great limestone beds. In color the shale varies from a black to a dirty green. The black shale is very hard, tough, and almost nonplastic and resembles roofing slate. Where it has been exposed to the weather it appears as a yellowish clay, full of thin flakes of harder material. These pieces are often rusty brown on the surface and still black in the core. The lower green layers of the shale are much softer and contain much less, frequently almost no carbon.

"A piece of the black shale thrown into the fire burns for a few minutes. Its carbonaceous matter consists prin-

cipally of bitumen, which volatilizes readily and burns as gas. The amount of this material is from 2 to 6 per cent.

"The iron in this shale owing to the large amount of carbon present is, of course, all in the lower state of oxidation, being present as ferrous carbonate and ferrous sulphide.

"This fact in connection with the large amount of organic matter makes this kind of shale exceedingly difficult to handle for the clay worker, though not interferring with cement making. While the bitumen is a great tribulation to the brick maker it would work beneficially to the cement manufacturer, inasmuch, as the carbon would help burn the cement mixture, making a considerable saving in the fuel expense, provided, of course, that the chemical composition of the shale otherwise is satisfactory."

Such a statement from an authority like Bleininger should be carefully considered. It points out the possible utilization of these black carbonaceous shales for which no economic use has so far been found, save their questionable adaptability for clay products and their former slight source of petroleum by distillation.[24] If these carbonaceous shales, as Bleininger suggests, have the otherwise proper chemical composition then they become a vast and imporant source of material for the manufacture of cement. The supply is unlimited in the region under discussion. The black, carbonaceous, Sunbury shale and the underlying and much thicker, black, carbonaceous, Ohio shale are developed throughout the region. There are probably a score of places where the shales could be easily quarried and at the same time be readily accessible to the various railroads. The necessary tests could be made at the instance of the survey or privately at a comparatively small cost. These tests should, by all means, precede the investment of capital.

24. The more "bituminous" sorts of these shales may possibly serve for the manufacture of producer gas, the residual slag being used for road material. if not for cement.—C. J. N.

THE BLACK SHALES AS A SOURCE OF COAL.

One of the chief functions of a geological survey is to prevent the needless investment of capital, as well as to point out the natural resources of the state. The New York Survey claims to have saved her citizens investment of vast sums of money in the search of coal in the Devonic black shales. It may seem a rather late date to discuss the subject for Kentucky, yet the authors found two men vigorously opening a mine in the Ohio shale. Members of other Surveys report similar experiences. It frequently is hard to convince these men that their efforts are futile, yet the warning note ought, probably, to be sounded again. For the benefit of all it should be stated that there is no coal of economic importance either in the black Sunbury shale or in the underlying black Ohio shale. The search for it in either of these black strata, therefore, is simply a waste of time and money. The coals occur at a higher geological horizon.

OIL AND GAS SANDS.

Strata of Waverlian age are important repositories of oil and gas (and also salt water) in Ohio, West Virginia, and Kentucky. Among the drillers of these States and oil men in general a nomenclature peculiar unto itself has sprung up. It is to be regretted that two sets of names are in existence, but the second seems to have also come to stay. It must be admitted, however, that this set is very convenient when the geologist does not wish to commit himself, and therefore follows the drillers record without change or interpretation. That portion of the set dealing with the Waverlian of Ohio will now be given in order to bring out the equivalent formations of the geological scale.

THE OHIO WAVERLIAN FORMATIONS AND SANDS.

Geological Scale.	Oil and Gas Scale.	
Formations.	Series.	Sands.
Logan	Big Injun series or Logan group.	Slate Keener sand Slate Big Injun sand Slate Squaw Sand
Black Hand		
Cuyahoga		
Sunbury		
Berea	Berea grit	Berea sand
Bedford		

PRODUCTIVE SANDS IN OHIO.

In Ohio the Berea above and below drainage covers more than a third of the state. According to Bownocker[25] a trace of oil or gas perhaps has been found in every county where the formation exists. It is being produced in commercial quantities from the grit in Lorain, Medina, Trumbull, Columbiana, Stark, Jefferson, Harrison, Belmont, Guernsey, Monroe, Noble, Vinton, Perry, Athens, Morgan, Meigs, and Washington counties. The Keener sand is an important source of oil in Monroe and Washington counties. The Big Injun sand has quite an extent in southeastern Ohio, but production of oil or gas from it in commercial quantities is limited to Monroe and Washington counties. The Squaw is of but very little importance even in Washington, the county of its best development.

PRODUCTIVE SANDS IN WEST VIRGINIA.

In West Virginia, White[26] places the Berea grit near the base of the Pocono sandstones, No. X. It is given as a productive oil and gas sand in Pleasants, Wood, Wirt,

25. Bownocker, John Adams, "The Occurrence and Exploitation of Petroleum and Natural Gas in Ohio," Geol. Surv. Ohio, Bull. 1, pp. 23, 25, 1903.

26. White, I. C. "Petroleum and Natural Gas," W. Va., Geol. Surv., Vol. I. (a), pp 79, 80, 1904.

Richie, Calhoun, Brooke, Handcock, and Cabell counties. The Big Injun, including the Keener, is made the top of the Pocono. In Monongalia, Marion and eastern Wetzel counties, the Big Injun contains a gas "pay" at 15 to 20 feet in the rock; a 1st oil "pay" at 60 to 75 feet; a 2nd or main one at 80 to 90 feet; and often a 3rd at 100 to 110 feet. In Tyler, Pleasants, Ritchie, and other counties, the uppermost 20 or 30 feet of the Big Injun is separated from the rest by shales. It is then called the Keener sand and is an important oil and gas zone.

PRODUCTIVE SANDS IN KENTUCKY.

In Kentucky, according to Hoeing[27], the Big Injun has been definitely recognized in Pike and Martin counties, where it is a source of gas in large quantities. It has also been identified in Magoffin, Johnson, Knox and Whitley counties. In a well near Barboursville, Knox county, it gave a large flow of gas. In Boyd county a sandstone, probably the Big Injun, yielded gas and salt water.

The same author further states that the Berea "has not been tested to any great extent in the Kentucky fields."

"Under cover the Berea grit will be found in all the counties east of an irregular line drawn from the mouth of Kinniconick creek in Lewis county to Torrent on the L. & E. Railroad (Wolfe County) and north of a line from Campton (Wolfe county) to Prestonburg on the Big Sandy river, but at increasing depth in proportion to its distance to the east. In the counties farther south it is probably not present, although but little drilling has been done to test it .....

"The Berea of Kentucky is of closer, finer grain than in Ohio, but wherever drilled through, shows more or less gas or oil, and as drilling progresses in the eastern counties, may prove to possess valuable oil fields within it limits."[28]

The discussion seems to have led far beyond the geographic limits of the paper, and yet oil and gas reservoirs,

27. Op. Cit. pp. 47, 48, 50.
28. Op. Cit. pp. 48, 50.

so important as those of the Waverlian, ought, at least in review, to be mentioned in the economic resources of the series. A detailed account of these important minerals of the series, on the other hand, may be had in the reports of Bownocker, White, and Hoeing, already mentioned. One phase of the subject, the thinning of the Bedford and Berea formations, ought to be of practical application and should, therefore, warrant further treatment. A few of the sections published by Hoeing (Bull. 1) will greatly aid in the elucidation of this point and will be given in part. In the selection of these sections only those have been chosen which show the black shales of both the Sunbury (Berea shale) and Ohio. For it does seem that a driller who fails to recognize the easily differentiated Sunbury shale would not be a safe man to follow in his other and more difficult divisions of the Waverlian. Furthermore, it seems more than probable that Hoeing has referred too great an interval to the Berea grit in many of the well sections as he did in the general section of Lewis county. This again is probably due to the development within the Bedford of sandstones which the driller could not separate from the Berea sandstones and both of which were, therefore, reported as sand. The partial section follows:

	Portsmouth, Ohio Well.	Ironton, Ohio Well.	Carter Co. Well, Grayson.	Well No. 4, Stinson creek.	Rowan Co. Well No. 2 N. E. Morehead 12 miles.	Lawrence Co. Well No. 4 mouth of Big Blain.	Well No. 5 mouth of Big Blain.	Morgan Co. Well, Caney.	Well No. 1 West Liberty.	Martin Co. Well No. 1.
Sunbury	30	20	22	10	10	27	10	7	25	18
Berea	50	47	†112	†116	†94	†60	†2	†24	*50	27
Bedford	50	90	*31	....	35	....	*80	*28	....	 20
Ohio	R	R	R	R	R	R	R	R	R	R
Total for Bedford and Berea	100	137	143	116	129	60	82	52	60	47

†At least a show of oil or gas. *Not identified. R—Reported.

To simplify the matter the records are assumed to be correct. They show that the Bedford-Berea intervals at Portsmouth and Ironton, Ohio, and in Carter county, Kentucky, are about normal in thickness. The same is true of the Rowan county well, but since this well is situated twelve miles north-east of Morehead and hence so near the county line, it could, for all practical purposes, be considered within the limits of Carter county. The wells to the south-east and south of the above territory, on the other hand, show a marked thinning. More specific, the Bedford-Berea intervals in wells of Lawrence, Martin and Morgan counties are of only about half the thickness of those of Carter county and vicinity. According to the well records then a similar thinning occurs in the Bedford-Berea interval to the southward under cover that was shown to occur to the southward along the line of outcrops, in Part I of this paper.

If the above conclusions are true then what? In the thinning of the Bedford-Berea under cover it is probable that the individual layers of sandstone also become thinner as they did in the outcrop sections. The final result would be either a shaly sandstone or arenaceous shale which would appear as "sand" in the drillings and probably would be reported as a sandstone. Now the question arises will a stratum of this kind contain oil or gas in commercial quantities? This is a question for the practical man to answer, but it should always be borne in mind when drilling to the Berea is contemplated.

Assuming the conditions found along the line of outcrop to further hold true under cover what would be the result? The arenaceous material would finally give way to argillaceous and nothing would be left except clay shales in the Bedford-Berea horizon. Hoeing gives a large number of sections in which it is impossible to divide the Waverlian into any of its formations from the records. In a few of these a thin zone of argillaceous shales capped by a few feet of black shales is shown in the very top of the Ohio (Devonic) black shales. It seems probable that the argillaceous zone represents the Bedford-Berea interval and the few feet of black shale above it, the Sunbury. Still

farther south the Bedford-Berea would become so thin that the drill would not reveal it. No one would think of drilling into the kind of a horizon pictured in this paragraph in the search for oil or gas and yet this is the probable Berea of a large part of Kentucky. The amount of drilling already done in much of the area is probably sufficient to prove the Berea to be this kind of a stratum.

Referring to map No. 2 of Hoeing's Bulletin, on Oil and Gas, the portion shown as the "area underlaid by Berea grit" is, no doubt, correct. But the Berea of those counties south of Carter is probably not the same kind of a stratum that it is in Ohio and West Virginia, where it is such an important source of oil and gas. In these counties it is more probable that the Berea consists of thin shaly sandstone or arenaceous shales, as has already been pointed out, while still further south it probably consists of argillaceous shales which finally grow so thin that they cannot be identified in the well records.

The practical question then arises, should the wells, after they have penetrated the very important sands of the Big Injun series, be continued in their search for oil and gas until they have reached the underlying Berea sand? A direct and definite answer will not be attempted since no one knows, definitely, what may be found. On the other hand it will only be pointed out what kind of a stratum may be expected, and leave the question whether or not the chance of the possible returns will justify the drilling of the extra two hundred to four or five hundred feet, to be settled by the parties concerned in each case. In the mapped Berea area south of Carter county, shaly sandstones or arenaceous shales may be expected. Still farther south argillaceous shales, probably, make up the stratum. And still farther south this stratum probably becomes thinner and thinner until its presence is not shown by an ordinary drill. If the Survey thus shows the probable outcome, so that the chances are knowingly taken, or, better yet, saves a needless expenditure of several hundred dollars in each well, it has served our citizens at least in one capacity.